DOCUMENT RESUME

ED 428 981 SO 029 098

AUTHOR	Smith, Rebecca L.; Leigh, Vicki; Crew, Diana Lee
TITLE	Prehistoric Journey: Denver Museum of Natural History Educators' Sourcebook.
INSTITUTION	Denver Museum of Natural History, CO.
PUB DATE	1995-00-00
NOTE	205p.
AVAILABLE FROM	Denver Museum of Natural History, 2001 Colorado Boulevard, Denver, CO 80205-5798; Tel: 303-370-6366 ($22).
PUB TYPE	Guides - Classroom - Teacher (052)
EDRS PRICE	MF01/PC09 Plus Postage.
DESCRIPTORS	Anthropology; *Archaeology; *Dinosaurs; Elementary Education; *Exhibits; Instructional Materials; *Museums; *Paleontology; Resource Centers; *Social Studies; Teaching Guides
IDENTIFIERS	Denver Museum of Natural History CO

ABSTRACT

This sourcebook prepares students for a visit to the "Prehistoric Journey" exhibit at the Denver Museum of Natural History. The exhibit opened October 23, 1995, and offered a dramatic exploration of 3.5 billion years of life on Earth. Dioramas and "enviroramas" depict seven critical points in life's history. In addition to the chronological presentation of life eras, the sourcebook presents activities, synopses of exhibits and tours, additional teacher resources, and suggestions for planning a visit to the museum. Articles and student handouts are included. (EH)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED 428 981

Prehistoric Journey: Denver Museum of Natural History Educators' Sourcebook.

BEST COPY AVAILABLE

SO 029 098

PERMISSION TO REPRODUCE AND
DISSEMINATE THIS MATERIAL HAS
BEEN GRANTED BY

Kristine A.
Haglund

TO THE EDUCATIONAL RESOURCES
INFORMATION CENTER (ERIC)
1

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION
CENTER (ERIC)

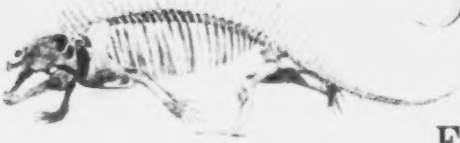
☑ This document has been reproduced as received from the person or organization originating it.

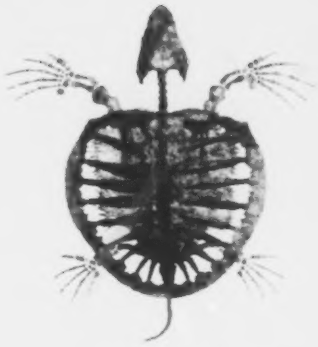
☐ Minor changes have been made to improve reproduction quality.

- Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

A TEACHER SOURCEBOOK

PREHISTORIC JOURNEY℠





Denver Museum of Natural History
EDUCATORS' SOURCEBOOK

The *Prehistoric Journey* Educators' Sourcebook Developed by:

Rebecca L. Smith,
Earth Sciences Educator

Vicki Leigh,
Education Assistant

and

Diana Lee Crew,
Manager of Youth Programs

Education Advisory Committee:

Thom Adorney
Marsha Barber
Diana Scheidle Bartos
Steve Gigliotti
Kay Bard Gray
Glen McGlathery
Pam Schmidt
Sharon Stroud

The Prehistoric Partners:

Anthony Arredondo
Maureen Arredondo
Jean Berres
Margie Leitner
Andy Leonard
Nancy Marosits
Karen Sangster
Gail Schatz
Sharon Shonaurt

Associates:

Dr. Vera Dawson
Dr. Sandy Husk
Alice James Sampson
Martha Uroste

Prehistoric Journey is a Denver Museum of Natural History Permanent Exhibition

SO029098

BEST COPY AVAILABLE

SCFD
Scientific & Cultural Facilities District

The Denver Museum of Natural History is a proud beneficiary of the Scientific and Cultural Facilities District.

We are using part of these resources to provide better and more affordable programs for schools in the six-county metropolitan area.

Special Thanks

We thank the following people for their preparation of and/or input into the following sections of this Sourcebook:

Thom Adorney and **Pam Schmidt:**
Self-guided tours

Thom Adorney:
Teacher Tip on *Teaching Evolution*

Marsha Barber and
Diana Scheidle Bartos:
Colorado State Standards information

Jean Berres:
How Do You Measure Up? Investigation

Steve Gigliotti: Field trips

Eddie Goldstein:
Radiometric Dating,
Evolution and Natural Selection,
Monster Math Investigation

Mark Hauck:
Fossilization, Biostratigraphy,
and Standards

Margie Leitner:
Prehistoric Parents Pages

Kathy McClintock:
Plate tectonics information

Karen Sangster, Mark Hauck
and **Leslie Newell:**
Tropical Rockies Activity

Gail Schatz:
Teacher Tip on *Planning Your Visit*

Pam Schmidt:
Sherlock Bones Investigation

Jeff Stephenson:
Radiometric Dating and
Origin of Life

Copyright © 1995 by Denver Museum of Natural History

The Denver Museum of Natural History gives permission for the reproduction of the student worksheets and parent pages of this Sourcebook for educational purposes.

THIS PUBLICATION WAS SUPPORTED IN PART BY FUNDING FROM THE NATIONAL SCIENCE FOUNDATION.

Educators' Sourcebook

We would like to thank the National Science Foundation, the Scientific and Cultural Facilities District, and the members of the Denver Museum of Natural History for their support of this Sourcebook.

Scientific background information and ideas for development of this manual: Dr. Richard Stucky and Dr. Kirk Johnson
Editorial Review: Karen M. Nein
Additional Review: Mary Bushbaum, Eddie Goldstein, Dr. Kirk Johnson, Frances Kruger, Brian McLaren, Beth Steinhorn, Jeff Stephenson, and Dr. Richard Stucky.
Additional Assistance: Polly Andrews, Elizabeth Arend, Norma Bovee, and Jill Carr.
Sourcebook Illustrators: Cover painting by John Gurche;
Marjorie Leggitt, Greg Michaels, Tom Buchanan, Cathy Holtz, Lisa McGuire, David Saitta, and Jill Souku
Photography: Rick Wicker, Dave McGrath, Richard Stum, Nancy Jenkins, Dr. Kirk Johnson, Rebecca Smith, and Beth Kaminsky
Graphic Design and Production: Kay F. Herndon, Danielle Dascalos, Lexie Foster, and Heidi Unhold

The following articles originally appeared in the Denver Museum of Natural History members' magazine, *Museum Quarterly,* managing editor, Todd Runestad.

Call It Synergy by Todd Runestad, *Recreating Ancient Forests* by Larry Sessions
The Day the Dinosaurs Died by Kirk Johnson, Spring 1995, Vol. 4, Issue 1, pp. 1–5.
Mammalian Ascendancy by Richard Stucky, Spring 1995, Vol. 4, Issue 1, pp. 6–7.
The Making of the Terminator Pig by Todd Runestad, Spring 1994, Vol. 3, Issue 1, pp. 9–12.
Around the World in 4.6 Billion Years: A Virtual Prehistoric Journey (7-part series) by Rebecca L. Smith.

Prehistoric Journey exhibit

Prehistoric Journey, the exhibit, was made possible only by the concerted and dedicated efforts of many individuals between 1989 and 1995. Portions of the exhibit content have been included in this Sourcebook.

Management Team: Brian McLaren, Richard Stucky, Rebecca Smith, and Merry Dooley
Interpretive Development Team: Frances Kruger, Kirk Johnson, and Rebecca Smith
Curation and Scientific Content: Kirk Johnson, Richard Stucky, Kenneth Carpenter, Tom Hardy, Logan Ivy, Jennifer Snyder, Elise Schloeder
Exhibit and Graphic Design: Robin Farrington, Allison Sundine, Bryce Snellgrove, Charles Stirum, Mike Coates, Carl Shipley, Scott Brown, Julie Langenthal, Lisa McGuire, Lexie Foster, Jim Marlow, Jack Augenblick, and Jim Leggitt
Fabrication and Carpentry: Bryan Bardwell, Dave Burdekin, Kevin Johnson, Rob Jurado, Marty Lechuga, Fred Jurado, Brian Wheeler, Victor Muñoz, John Dilgarde, Jeff Yearick, Ken Portuese, and Dana Seymour
Lighting and Special Effects: Charles Stirum, Daniel Gonzales, and Zachary Reynolds
Videos and Computer Animation: David Baysinger, Eric Klepinger, Elizabeth Gilmore, and Terry Trieu
Fossil Preparation: Kenneth Carpenter, Bryan Small, Jon Christians, Jennifer Moerman, Jerry Harris, Karen Alf, Linda Smith, and Bill May
Illustrations: Greg Michaels, Marjorie Leggitt, and Tom Buchanan
Photography: Nancy Jenkins, Rick Wicker, David Shrader, Gary Hall, Dave McGrath, Richard Stum, and Beth Kaminsky
Administration: Libbie Gottschalk, Marianne Reynolds, Sheila Mutchler, Alan Espenlaub, Curt Simmons, Karen Arnedo, Patricia Jablonsky, Jim Goddard, and Jane Day
Interpretation: Frances Kruger, James Alton, and Judy Schaefer
Evaluation: Margaret Marino, Dr. Ross Loomis, Mark Harvey, and Beth Kaminsky
Sculpture: Tom Shankster, Dennis McElvain, Gary Staab, Mark Akerley, and John Gurche
Foregrounds: Elizabeth Marshall, Hugh Watson, Denise Patton, Leonard Koenig, Jayme Irvin, and Claudette Wallace
Murals: Jan Vriesen, Deborah Vriesen, Kent Pendleton, Terry Chase, Jeff Wrona, Chuck Parson, and Tom Buchanan
Education: Rebecca Smith, Eddie Goldstein, Jeff Stephenson, Kathy Kuba, and Merry Dooley
Development: Anne Fothergill and Bonnie Downing
Marketing: Peggy Day, Amy Tekansik
Scientific Consultants: Allison R. Palmer, Reuben Ross, William Cobban, Leo J. Hickey, William DiMichele, Howard Feldman, Gene and Royal Mapes, Don and Joanne Mikulic, Hermann Pfefferkorn, Sidney Ash, Douglas Nichols, Joe Thomasson, Lynn Margulis, Sergius Mamay, Scott Wing, Garland Upchurch, Cathy Whitlock, Leonard Krishtalka, Robert Hunt, and Malcolm McKenna
Education Advisory Committee: Thom Adorney, Marsha Barber, Diana Scheidle Bartos, Ann Bell, Steve Gigliotti, Kay Bard Gray, Glen McGlathery, Pam Schmidt, Nancy Songer, and Sharon Stroud
Museum Volunteers: Many volunteers contributed their time and skills to *Prehistoric Journey*.

PREHISTORIC JOURNEY

Dear teacher,

Prehistoric Journey, the Museum's newest permanent exhibition, opened to schools October 23, 1995. The exhibition offers a dramatic exploration of 3.5 billion years of life on Earth. Engaging dioramas and "enviroramas" (walk-through exhibits with sound and light effects) depict seven critical points in life's history. The exhibition is also the new home for the Museum's dinosaurs.

We are using *Prehistoric Journey* as a testing ground for improving the quality of school visits to the Museum. We have worked with teachers throughout the Denver metropolitan area and Colorado Springs since 1991 to ensure that the exhibition content and related materials meet your needs and address district, state, and national standards for science teaching. Students will be able to explore the exhibition in groups of no more than 18, separated from other groups by a timed entry system.

This Sourcebook will prepare you for visit after visit to this rich and exciting educational exhibition. By using this Sourcebook in concert with additional resources such as the pre-visit video (with segments for students and teachers), teacher workshops (with presentations by Museum scientists), and the *Prehistoric Journey : A History of Life on Earth* exhibit book, you can bring the past to life and open up a whole new prehistoric world for your students.

We hope your visit to *Prehistoric Journey* is only the beginning of an exciting new discovery of the history of life on Earth.

Enjoy!

Rebecca L. Smith

Rebecca L. Smith
Earth Sciences Educator

Diana Lee Crew
Manager of Youth Programs

Denver Museum of
Natural History

2001 Colorado Boulevard
Denver, Colorado • 80205-5798

PREHISTORIC JOURNEY

EDUCATORS' SOURCEBOOK

FEATURES

Origin of Fish mural
Fish were the first vertebrates.
Pages 33 and 36

Early Life **Evidence Area**
Touch a bronze sculpture of this giant, 530-million-year-old trilobite.
Page 25

PREHISTORIC JOURNEY: INTRODUCTION

8 The Sourcebook at a Glance
9 The Exhibit at a Glance
10 An Educational Experience of Epic Proportions–*Prehistoric Journey* educational goals
11 Creating *Prehistoric Journey*

PREHISTORIC JOURNEY: OVERVIEW

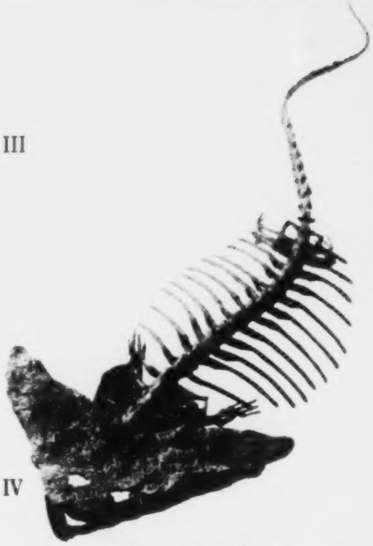
14 Come Take a Trail Through Time!
Trail Guide (insert in front pocket of notebook)
15 Time Travel Theater
15 Taking the Trail Through Time
16 Focusing on Learning in the Evidence Areas
17 Telling Time at the Time Stations
18 Geological Time

21 EARLY LIFE
22 Precambrian Era
  23 Around the World in 4.6 Billion Years: A Virtual *Prehistoric Journey*, Episode I
  24 *Ancient Sea Floor* Diorama
  25 *Early Life* Evidence Area Map
  Background information on
    26 How Old Is the Earth
    26 How Radiometric Dating Works
    27 The Origin of Life
    27 Explosion of Life

28 Paleozoic Era
  29 Paleozoic Time Station
  Background information on
    30 Where's Colorado?–Plate Tectonics
    Where Are You in Time?
  32 DIVERSITY IN THE SEA
  33 Around the World in 4.6 Billion Years: A Virtual *Prehistoric Journey*, Episode II
  34 *Sea Lily Reef* Diorama
  36 *Diversity in the Sea* Evidence Area Map
  Background information on
    37 Which Rocks Are Older?
    Everything's Relative
    How Living Things Become Fossils
    How Things Turn to Stone
    38 A Trilobite Finds a Home in *Prehistoric Journey*

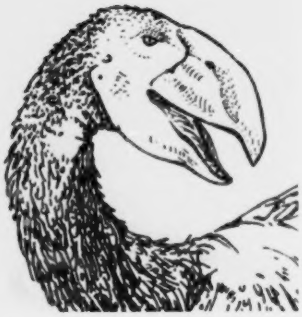
Paleozoic Era (continued)

39 LEAVING THE WATER—Trailside Discovery Camp and Staircase
41 Around the World in 4.6 Billion Years: A Virtual *Prehistoric Journey,* Episode III
42 *Between Two Worlds* Diorama
43 *Leaving the Water* Evidence Area Map
Background information on
44 Why Study Evolution?
How Evolution Works
45 Natural Selection
46 Genetic Drift
See for Yourself How Natural Selection Works
47 Teacher Tip: Teaching Evolution
48 FORESTS AND FLIGHT
49 Around the World in 4.6 Billion Years: A Virtual *Prehistoric Journey,* Episode IV
50 *Kansas Coastline* Diorama
51 *Forests and Flight* Evidence Area Map
Background information on
52 Modern Greenhouse
53 Insects Begin to Fly



Forests and Flight Evidence Area
275-million-year-old
amphibian fossil
Page 51

54 **Mesozoic Era**
55 Mesozoic Time Station
56 TIME OF THE DINOSAURS
57 Around the World in 4.6 Billion Years: A Virtual *Prehistoric Journey,* Episode V
60 *Cretaceous Creekbed* Envirorama
62 *Time of the Dinosaurs* Evidence Area Map
Background information on
64 Dinosaurs and Their Relatives
65 What Is a Dinosaur?
66 Scavenger Hunt
67 Fight to the Finish?
68 A World Without Flowers
69 A Flowering of Plants
70 The End of the Dinosaurs



Tropical Rockies Evidence Area
Diatryma
A giant, flightless, vicious predator
Page 79

Expanding Grasslands Evidence Area
3-million-year-old
Australopithecus afarensis cast

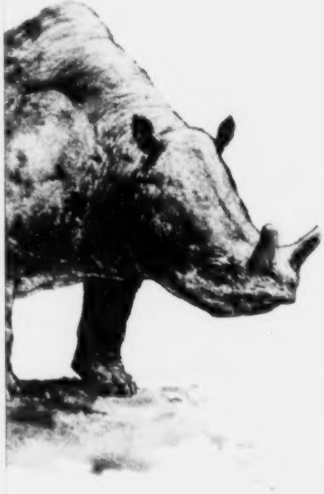
Page 90

74 Cenozoic Era
75 Cenozoic Time Station
76 TROPICAL ROCKIES
77 Around the World in 4.6 Billion Years: A Virtual *Prehistoric Journey*, Episode VI
78 *Rainforest Treetop* Diorama
79 *Tropical Rockies* Evidence Area Map
Background information on
80 Mammalian Ascendancy
82 Legacy of Life in the Trees
83 What Is a Species?
Why Did the Mammals Change?
84 Ancestors of Modern Mammals
86 EXPANDING GRASSLANDS
87 Around the World in 4.6 Billion Years: A Virtual *Prehistoric Journey*, Episode VII
88 *Nebraska Woodland* Envirorama
90 *Expanding Grasslands* Evidence Area Map
Background information on
91 The Making of the Terminator Pig
93 Life in the Cenozoic Seas
94 Where Did We Come From?
95 The Story of Us
96 EARTH SCIENCES
97 Paleontology Laboratory: Unearthing the Past
98 The Earth Has a History

PREHISTORIC JOURNEY: HITTING THE TRAIL

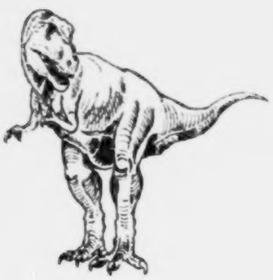
100 TOURS AND INVESTIGATIONS
101 Colorado State Teaching Standards
102 **Hitting the Trail Guided Tours With a Museum Tour Guide!**
Dinosaurs and Other Prehistoric Life (Grades K–3)
Ecosystems and Adaptations (Grades 3–8)
How Do We Know?: Advanced Ecosystems and Adaptations (Grades 6–12)
103 Blazing Your Own Trail Self-Guided Tours
104 Experiencing Evolution (Grades 4–12)
110 Earth Processes: How Do We Know? (Grades 6–College)
117 Trail Map

Expanding Grasslands Evidence Area
Dinohyus hollandi
Page 90



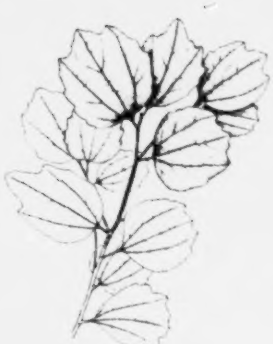
Expanding Grasslands illustration
20 million years ago,
Earth's climate began to cool and become drier. Forests began to recede; mammals and primates underwent many changes.

Pages 90



Monster Math Investigation

Page 122



Leaf Count Investigation

Page 134

INVESTIGATION ACTIVITIES

119 How Do You Measure Up? (Grades K–4)
- 120 Dinosaur Footprints (pre-visit)
- 122 Monster Math (pre-visit)
- 126 Sizing Up the Past (museum visit)
- 128 Dinosaur Scenes (post-visit)
- 130 Additional Dinosaur Activities
  - Discover a Dinosaur
  - Learn the Lengths of Dinosaurs
  - Be a Dinosaur Poet
- 131 Dinosaur Rap Poem

132 Fossil Leaf Litter (Grades 4–10)
- 133 Take a Hike Around Your School (pre-visit)
- 142 Classify a Creekbed (museum visit)
- 143 Leaving Leaves (post-visit)
- 144 Additional Plant Activity: Tropical Rockies

146 Sherlock Bones (Grades 6–College)
- 148 Mystery of Prehistory Part I (pre-visit)
- 152 Visit an Actual Bonebed (museum visit)
- 154 Mystery of Prehistory Part II (post-visit)

157 Additional Prehistoric Life Activities

158 Involving Parents in the *Prehistoric Journey* Experience
- 159 Fun for Prehistoric Parents

ADDITIONAL TEACHER RESOURCES

163 Colorado Connections: Local Fossil Finds and Field Trips
- 165 Fossil Collection Considerations
- 166 Bibliography
- 171 **Glossary**

PREHISTORIC JOURNEY: POINTERS

179 Planning Your Visit
- 180 Hours, Pricing, Scheduling Your Visit, When You Arrive, Late Arrivals, Rescheduling, Cancellations, Teacher Tip

181 Related Program
- Teacher Workshops, Classroom Adventures, Exhibit Catalog, Tours, Pre-Visit Teacher Video, Planetarium Show, WOW Outreach Programs, Gallery Presentations, Adult Programs, Museum Shop

PREHISTORIC JOURNEY: APPENDIX

184 Correlation of *Prehistoric Journey* and the Adopted Colorado State Standards

187 Teacher Sourcebook Evaluation Form

Sizing Up the Past Investigation

Page 127

Prehistoric
Universe

Planetarium Show
Recommended for grades 5 and up

Page 182

SOURCEBOOK SYMBOLS

Evidence Area Maps:

MAGNIFYING GLASS
indicates discovery
elements in exhibit

BOOK FORMAT
indicates study elements
in exhibit

1 **HAND SYMBOL**
turn the page for additional
background information
corresponding with number

Self-Guided Tours:
see page 103

PACING YOUR TOUR

KEY CONCEPT

OPTIONAL

Investigations section:
see page 118

PRE-VISIT ACTIVITY

MUSEUM ACTIVITY

POST VISIT ACTIVITY

THE SOURCEBOOK AT A GLANCE

PLANNING A VISIT?

Dioramas, Evidence Areas, and Time Stations are the heart of the exhibit.

Diorama identifications: Turn to **pages 24, 34–35, 42, 50, 60–61, 78, 88–89.**

Maps of the Evidence Areas: Turn to the seven maps on **pages 25, 36, 43, 51, 62–63, 79, 90.**

Time Station identifications: Turn to **pages 28–31, 54–55, 74–74.**

WANT MORE INFORMATION ON GEOLOGIC TIME?

Turn to **pages 18–19.**

For your information: M.Y.A.: million years ago B.Y.A.: billion years ago Y.A.: year ago

WOULD YOU LIKE A GUIDED TOUR?

Turn to **page 102** to learn more about our guided tours.
To schedule a guided tour, turn to **page 180** in *Prehistoric Journey* Pointers.

SELF-GUIDED TOURS

To take your classroom on a self-guided tour, turn to **pages 103–116.**

TEACHER TIPS

Look for informative and fun tips from local teachers.

PLANNING YOUR CURRICULUM?

Turn to the Investigations section on **pages 118–160.**
Each Investigation includes pre-visit, during- and post-visit activities.

PLANNING A FIELD TRIP?

Turn to **pages 162–164** for information about field trips that will enhance your curriculum.
Get informed about the legal and ethical considerations of fossil collecting on **page 165.**

NEED A WORD DEFINED?

Turn to the glossary on **pages 171–178.**

LOOKING FOR ADDITIONAL RESOURCES?

On **pages 166–170** in the bibliography, you will find many suggestions of informative books, magazine articles, teacher activity sources, and student books to help you and your students learn more about the history of life on Earth.

PREHISTORIC JOURNEY POINTERS

For more information about other Museum resources such as *Prehistoric Journey*–related classes, teacher workshops, and planetarium shows, and how to schedule them, turn to **pages 179–183.**

HOW DOES *PREHISTORIC JOURNEY* RELATE TO THE COLORADO STATE STANDARDS FOR TEACHING?

Turn to **pages 101 and 184–186.**

THE EXHIBIT AT A GLANCE

EXHIBITION GOALS

1. To inspire an appreciation for the immensity of time and the amount of change since life first began on Earth.
2. To demonstrate that many different sciences and types of technology contribute to our understanding of the past.
3. To demonstrate the importance of examining the history of life on Earth in light of current environmental issues.

TAKING THE TRAIL THROUGH TIME

PRECAMBRIAN ERA—4.6 billion years ago to 545 million years ago

Time Travel Theater
Early Earth—4.6 billion years ago
Origin of Life—3.5 billion years ago

***Ancient Sea Floor* Diorama**—600 million years ago; Ediacara Hills, South Australia
***Early Life* Evidence Area**

PALEOZOIC ERA—545 million years ago to 251 million years ago

Paleozoic Time Station

***Sea Lily Reef* Diorama**—425 million years ago; Racine, Wisconsin
***Diversity in the Sea* Evidence Area**

***Between Two Worlds* Diorama**—395 million years ago; Beartooth Butte, Wyoming
***Leaving the Water* Evidence Area**

***Kansas Coastline* Envirorama**—295 million years ago; Hamilton, Kansas
***Forests and Flight* Evidence Area**

MESOZOIC ERA—251 million years ago to 65 million years ago

Mesozoic Time Station

***Cretaceous Creekbed* Envirorama**—66 million years ago; Marmarth, North Dakota
***Time of the Dinosaurs* Evidence Area**

CENOZOIC ERA—65 million years ago to Present

Cenozoic Time Station

***Rainforest Treetop* Diorama**—50 million years ago; Lost Cabin, Wyoming
***Tropical Rockies* Evidence Area**

***Nebraska Woodland* Envirorama**—20 million years ago; Agate Springs, Nebraska
***Expanding Grasslands* Evidence Area**

Paleontology Lab
The Journey Continues

PREHISTORIC
JOURNEY

INCLUDES:

- Seven (7) dioramas or enviroramas along the trail
- Over five hundred (500) fossils
- More than thirty (30) articulated skeletons, including ten (10) dinosaurs
- Five (5) videos
- Five (5) computer interactives
- Twenty-nine (29) hands-on interactives
- Thirteen (13) touch specimens
- Eleven (11) study elements
- Approximately thirty (30) discovery elements
- Trailside Discovery Camp with many fossils and other hands-on specimens
- Fossil preparation lab with public viewing window

PREHISTORIC JOURNEY

Prehistoric Journey offers a whole new world of discovery for young people.

An Educational Experience of EPIC PROPORTIONS

Imagine visiting an ancient ocean teeming with life, strolling through a primordial forest with giant buzzing insects, or taking a path over a rushing creek where nearby male dinosaurs spar for the attention of a female. These scenes are just some of the events in the 3.5-billion-year history of life on Earth you will experience on your *Prehistoric Journey*. This trend-setting, major permanent exhibition has been six years in the making. *Prehistoric Journey* allows you to explore ancient environments (re-created from scientific research conducted by Museum paleontologists) and to view spectacular, world-class fossil specimens from Colorado, the Rocky Mountain region, and other areas of the world, including Denver's favorite dinosaurs, repositioned into new dramatic poses.

Prehistoric Journey will excite your students about science. They will see the direct results of scientific investigation. Cases with fossil and geological evidence are immediately adjacent to the environments that were re-created from specific fossil sites. Students will try their own hands at solving prehistoric puzzles—how many skeletons are there in a fossil rhinoceros bone bed? How old is a piece of Pikes Peak granite? Students also will be able to touch fossils, as well as a piece of the oldest rock on Earth—a rock nearly 4 billion years old.

Educational Goals of *Prehistoric Journey*

***Prehistoric Journey* will inspire an appreciation for the immensity of time and the amount of change since life first began on Earth.** After viewing the *Time Travel Theater*, which will take you and your students back in time to the early Earth and the origins of life, you will take a trail through ancient environments that tell the story of life on Earth. Along this trail, your students will find that **the Earth is very old and that its climate and life-forms have changed greatly in the past and are still changing**. They will discover that **many different sciences and types of technology contribute to our understanding of the past.** Chemistry, geology, physics, botany and remote sensing, computer modeling, and X-ray technology help paleontologists understand Earth's history. Students will be able to **examine the history of life on Earth in light of current environmental issues**, identifying events of the past, such as global warming, cooling, and extinction episodes, that provide the scientific foundation that allows us to address current environmental issues and concerns. Global changes occurring now may have parallels in the planet's past. We want today's students to realize that **we can learn a lot from the past**.

The Education Division of the Denver Museum of Natural History strives to develop programs and educational materials that will support existing curriculum and content standards of Colorado schools. The educational goals of *Prehistoric Journey* directly support many of the Colorado Model Content Standards for science teaching. Specific standards that relate to *Prehistoric Journey* tours and activities are referenced within this Sourcebook. A summary of relevant standards are in the appendix located in the back of this Sourcebook.

In addition to science standards, *Prehistoric Journey* can serve as a source for fun ideas in teaching reading, writing, math, geography, and history. We believe effective science education incorporates many disciplines, allowing students with different academic strengths to enjoy exploring the dynamic world of scientific investigation. You can excite students about learning by having them

- *estimate the size of a dinosaur from the length of its femur,*
- *study the geographical distribution of dinosaur finds around the globe,*
- *write a story about having a pet woolly mammoth,*
- *read about the discovery of fossils by young people, or*
- *learn how a mouse helped scientists discover how photosynthesis works.*

Creating PREHISTORIC JOURNEY

Trekking through hundreds of million of years, covering 17,000 square feet of exhibit space, and peering into scenes from Earth's history will be both exhilarating and mystifying for your students. How did this incredible journey come about? What did it take to make *Prehistoric Journey* a reality? The collective energies of 65 staff members and more than 200 volunteers with vast and varied experiences have come together over a span of 6 years to produce this amazing exhibit.

Many aspects of *Prehistoric Journey* just naturally stand out—the rock work along the trail; the luminescent ancient sea floor; the beautifully painted murals; the interactive computer games; and the giant dinosaurs, rhinos, and mammoths. The rigorous detail with which scientific accuracy is maintained, special effects such as lighting and sound, models of unusual plants and animals from the past, and a real rushing creek also make the exhibition a paradise for students of prehistory.

Many teams worked together to develop, design, and build *Prehistoric Journey.* Some careers represented in these teams include the following:

MANAGEMENT TEAM
A project manager, project science director, project education director, and administrative assistant oversaw the progress of the project. The project manager, with input from other management team members, directed the project and ensured that it was proceeding within the determined budget and time constraints.

INTERPRETIVE DEVELOPMENT TEAM
An exhibit developer, an educator, and a paleontology curator worked together to organize the exhibit content, create teaching points, and draft labels. The exhibit developer-interpretive writer wrote the final exhibit labels; editors and proofreaders went over them with a fine-tooth comb.

EARTH SCIENCES TEAM
Paleontology curators, science advisors, a collections manager, fossil preparators, and volunteers conducted research, compiled scientific information and resources, and acquired and prepared specimens.

DESIGN TEAM
Exhibit designers, architects, draftspersons, and lighting and special effects experts designed and created the exhibit and its special effects.

Continued on next page

Jon Christians positions the skeletal head of *Allosaurus*.

CALL IT SYNERGY

In the past, many museum exhibitions were mostly the product of scholarly work—both in and out of the field—of the curatorial staff. And while the result of a curator's efforts may have been appealing to the curator's peers, very often it went over the heads of the very people the exhibition was supposed to hold meaning for: the museum visitors.

The Denver Museum of Natural History, however, is at the forefront of a new paradigm, and nowhere is this example more evident than in *Prehistoric Journey.* The central tenet in this new method of assembling exhibitions is teamwork. For *Prehistoric Journey*, the scientific, education, and exhibit staffs have formed a cohesive unit that works by sharing all of their vast and varied expertise.

Curator of Paleontology Dr. Richard Stucky likes the way this approach has helped make the scientific side of the exhibition easier to understand. "The interpretive writers fill in the holes that we can't provide from our fieldwork," he says. "It's an integrated process that I suspect will result in the most visitor-friendly exhibition visitors are likely to see anywhere."

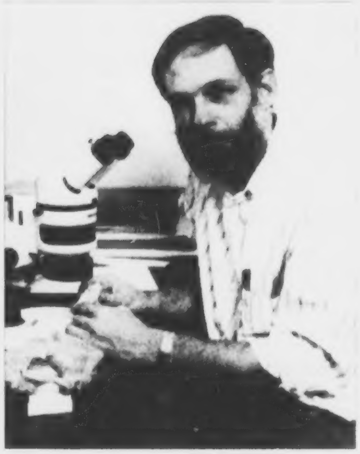
> *"As an interpretive team, we're pulling together the best of all three, the scientist, the educator, and the exhibition specialist. Somebody like Dr. Stucky provides the fossil evidence. We provide the romance."*
>
> — **Frances Kruger**
> Exhibit Developer–Interpretive Writer

Creating PREHISTORIC JOURNEY

The exhibit curators, Dr. Richard Stucky and Dr. Kirk Johnson, have taken an ecological perspective when re-creating life on Earth, allowing visitors to view the history of life as a series of interlinked and ever changing ecosystems filled with amazingly diverse and evolving organisms. The curators chose six western interior localities from North America and one Australian locality that have extraordinary fossil sites to reconstruct as dioramas and enviroramas. These reconstructions are based on research and fieldwork by Museum paleontologists and on publications and conversations with their scientific advisors.

A prehistoric turtle slowly emerges from the hands of Gary Staab.

Tom Shankster brings a 20-million-year-old *Dinohyus* back to life.



Dr. Richard Stucky

Curator of Paleontology
Denver Museum of Natural History

The Past Is the Key to the Present

Museums are places where the public's treasured objects are kept. When I was a kid, we vacationed in the Rocky Mountains every year, and each trip included a visit to the Denver Museum of Natural History. Seeing all the fascinating objects housed in the Museum sparked in me an early interest in becoming a museum curator.

As a curator, I am responsible for preserving rare specimens and objects for future generations. I'm also responsible for documenting the stories behind them. What we preserve today will enhance our knowledge of the world and of science well into the future. But we also use what we've preserved in the present for many purposes including research, education, and exhibition.

FOREGROUNDS AND TAXIDERMY TEAM
Sculptors, foregrounds preparators, and volunteers created the foregrounds (leaves, trees, riverbed, rock cliffs, and so forth) and sculptures of plants and animals for the exhibit.

MULTIMEDIA TEAM
Computer programmers, electronic media specialists, and video producers created the computer interactives and videos for the exhibit.

GRAPHICS TEAM
Graphic designers, muralists, silk-screen artists, and scientific illustrators created the murals, illustrations, graphics, and text panels for the exhibit.

PRODUCTION AND INSTALLATION TEAM
Carpenters built the cabinetry and other woodwork for the exhibit. Exhibit preparators and mount makers prepared, mounted, and installed fossils and other exhibit components.

EVALUATION TEAM
An exhibit evaluator and volunteers tested exhibit elements with the public to ensure that they are understandable, fun, and educational.

Dr. Kirk Johnson

Curator of Paleontology

Denver Museum of Natural History

Driving Interest

Wherever I am, I'm aware of the rocks that surround me. Whenever I drive somewhere, I watch the geologic formations like a kid watches cartoons. For me, the history of life on Earth is on constant display.

Living in Denver is a real treat for a paleontologist. Within a few miles of my office are the remains of ancient rainforests, dinosaur trackways, and the site where Triceratops*—my favorite dinosaur—was first discovered. In the last few years, we've excavated a partial* Tyrannosaurus rex *skeleton, a mammoth tusk, shells of prehistoric marine animals, and fossil palm fronds—all within the Denver metropolitan area!*

PHOTOGRAPHY TEAM

Photographers and video producers documented the exhibit development process, acquired images and permissions, and produced photographs and video footage for the exhibit.

EDUCATION TEAM

Educators, an education collections coordinator, program managers, teachers, and volunteers created educational materials and programs such as tours, gallery presentations, classes, and workshops that accompany the exhibit.

MARKETING TEAM

Marketing specialists planned a marketing strategy, promoted the exhibit to the public, and informed the media about the exhibit and the exhibit development process.

DEVELOPMENT TEAM

Fund-raising and grant-writing specialists raised the money to build the exhibit.

THE VISITOR

Coupled with a teamwork approach is making sure the exhibition takes into account the great diversity of people who will visit the Museum. For *Prehistoric Journey,* Museum staff has separated visitors into three broad groups: discoverers, explorers, and studiers. "People can come in and be any of them on any day," says Rebecca Smith.

"Prehistoric Journey *will be so rich that people can visit many times and still get something new each time.*"

—Rebecca Smith

Earth Sciences Educator and member of the interpretive and management teams

Hugh Watson combines fossil evidence and specimens of living relatives to create trees that were alive millions of years ago.

Denise Patton paints finishing touches on a rock wall in *Prehistoric Journey.*

BEST COPY AVAILABLE

PREHISTORIC JOURNEY℠

Prehistoric Journey is a rich educational resource that provides the opportunity for numerous visits, each of which can be a different adventure in time. Your journey begins with the **Time Travel Theater,** a state-of-the-art video presentation that prepares you for your trek back through time. It is time to leave the modern world of high-rise offices, congested traffic, and television behind and travel to the Earth's beginnings and the origin of life. After viewing the video, you will enter an undersea world. Along the way, the **Trail** passes through reconstructed environments from specific locations throughout North America (and one from Australia). After experiencing each environment, you can choose to enter the adjacent **Evidence Area** and study the exhibit case with evidence for the environmental reconstruction.

In the Evidence Area, you can also view and touch fossil specimens and experiment with interactive exhibits. Three levels of interest are available: **Discovery**, geared toward the casual visitor and made up of highly interactive components covering basic science concepts; **Exploration,** carrying the main story line of the exhibit; and **Study** that provides students with a greater depth of information on specific topics.

You can get an in-depth picture of the time period before returning to the Trail and viewing the diorama or envirorama again with "new eyes."

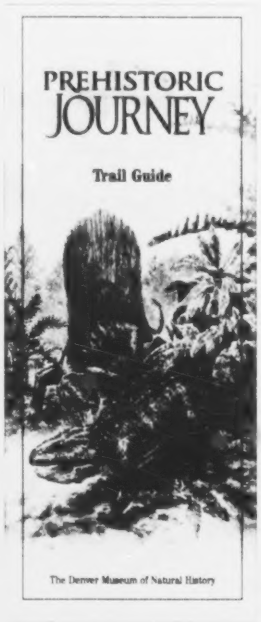
In the **Trailside Discovery Camp,** staffed by Museum volunteers, your class can engage in fun activities, examine fossils, and participate in scientific demonstrations (at specified times).

At the **Paleontology Laboratory,** you will see the fossils the Museum is currently preparing, new fossil discoveries, and the methods used to prepare fossils for research and display.

COME TAKE A TRAIL THROUGH TIME!

TRAIL GUIDE

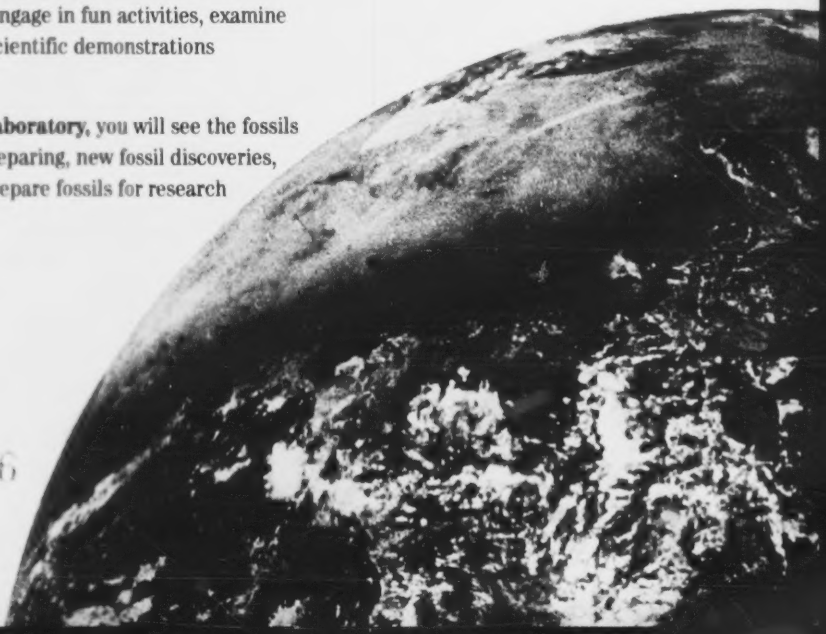
The Trail Guide (included with this Sourcebook) is an informative map of the exhibit that you should use in planning and conducting tours and activities in the exhibition.



PREHISTORIC JOURNEY

Trail Guide

The Denver Museum of Natural History



THE JOURNEY BEGINS

TIME TRAVEL THEATER

The journey begins in the Time Travel Theater, just inside the exhibit entrance, which has the feel of a national park—complete with wooden benches. Here, a three-minute video presentation will take you back in time.

Modern life is diverse—filling water, land, and air. But 4.5 billion years ago, when the Earth formed, there was no life, no water, and no air as we know it. It took a long, long time for Earth's patterns to establish, and for life to brew slowly from nonlife.

You and your students will exit from the Time Travel Theater into the dark, watery world of the *Ancient Sea Floor*.

TAKING THE TRAIL THROUGH TIME

The Trail will lead you on your journey through time. You can recognize the Trail by its pebbly surface beneath your feet. Along the way, the Trail passes through reconstructed environments (dioramas and enviroramas) from specific locations throughout North America (and one from Australia). Connected to each environment is an Evidence Area. Evidence Areas loop off the Trail for greater exploration and learning—returning to the trail, you can view the dioramas again with "new eyes." You can choose to remain on the Trail or visit adjacent Evidence Areas depending on the amount of time you have and the depth in which you want to study different subjects.

NOTE: Unlike the other Evidence Areas, the Trail actually **goes through** the *Time of the Dinosaurs* and *Expanding Grasslands* Evidence Areas.

The early Earth

FOCUSING ON LEARNING IN THE EVIDENCE AREAS

Each of the seven Evidence Areas contains

- An **Evidence Case** that displays and interprets the evidence for the environmental reconstructions (dioramas and enviroramas)
- Interpretive exhibit cases exploring developments during that period of Earth's history
- Spectacular fossil specimens
- Interactive exhibits and touch specimens
- Evidence areas that loop off the main trail for greater exploration and learning, and to give you a chance to view the dioramas again with "new eyes"

ATTENTION PLEASE . . .

There are lots of fossils for students to touch in *Prehistoric Journey*. Please have them leave the others alone, even if they can reach them. **Fossils are fragile and irreplaceable.**

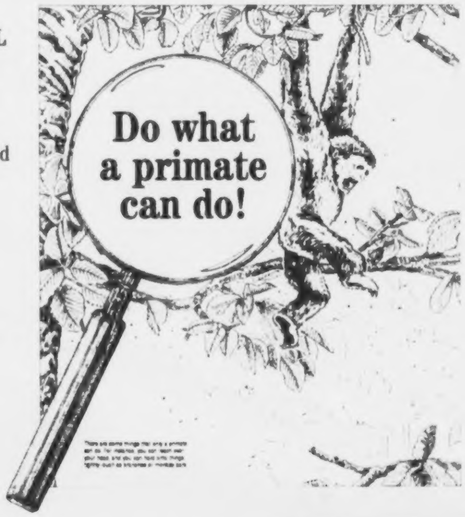
The Evidence Areas contain information on three levels:

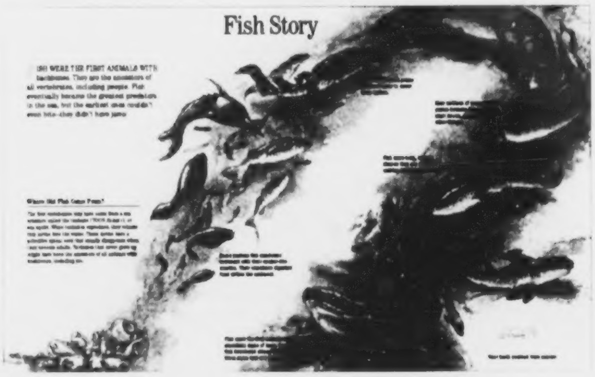
1

DISCOVERY LEVEL

Discovery Elements can be recognized by a magnifying glass symbol, and are geared toward children and the casual visitor.

These elements are made up of highly interactive components covering basic science concepts. They look like this.





2

EXPLORATION LEVEL

The main story line of the exhibit is the **Exploration Level.** Exhibit elements and panels not identified by either the magnifying glass symbol or the book format are Exploration Level.

3

STUDY LEVEL

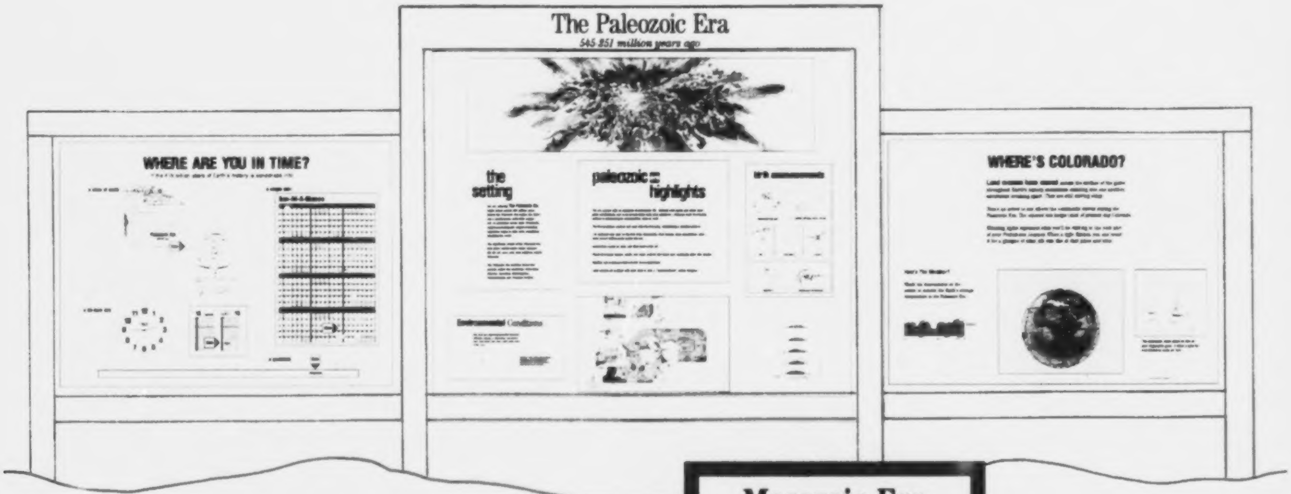
Study Elements provide a greater depth of information on specific topics and can be recognized by the "book" format. They look like this.

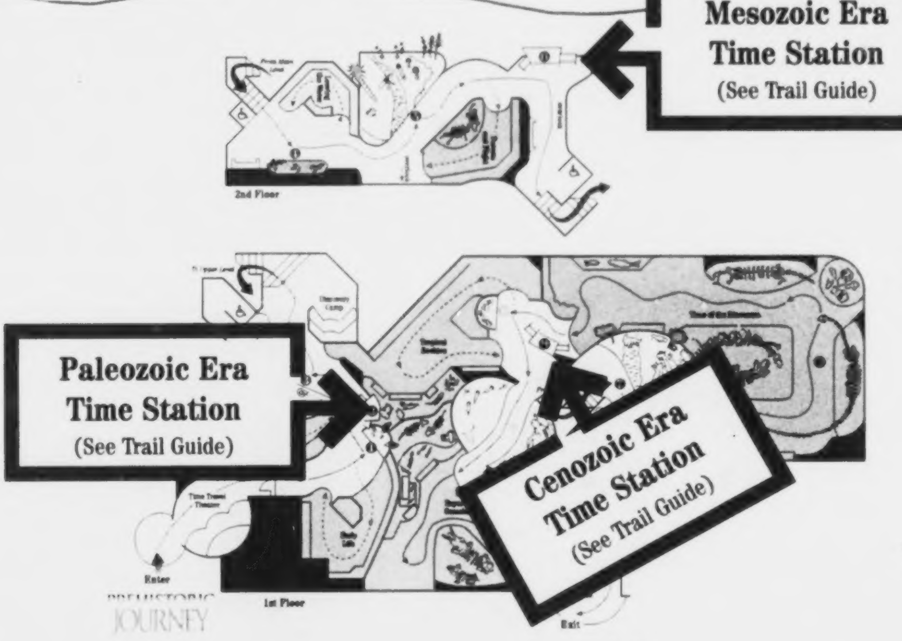
TELLING TIME AT THE TIME STATIONS

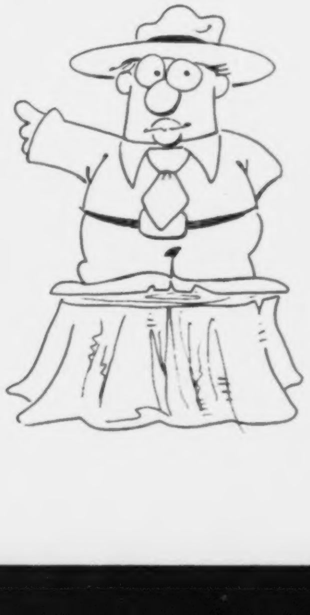
There are three Time Stations in the exhibit. The Time Stations highlight the **Paleozoic Era**, the **Mesozoic Era**, and the **Cenozoic Era** (the Precambrian Era was prior to these eras and is not the focus of a Time Station). Here your students can find out where they are in time. The Time Stations use several different time analogies to help students grasp the immensity of geologic time and place them within a specific time period. The Time Stations also give setting descriptions, highlights of the era, environmental conditions, birth and death announcements (what groups of organisms arose and became extinct), and explain where Colorado was at the time.

At the Time Stations, students should note the following:

1. The continents have always shifted around on the Earth's surface and are still doing so today.
2. The categories scientists use to describe geologic time include big chunks of time (eras) that are subdivided into smaller units (periods and epochs).
3. Units of geologic time are defined by extinctions (deaths) at the end of one unit, followed by radiations (births) at the beginning of the next.
4. Humans did not evolve until very, very recently in geologic time.


The Paleozoic Era
545-251 million years ago
WHERE ARE YOU IN TIME?
the setting
paleozoic highlights
Environmental Conditions
WHERE'S COLORADO?


Mesozoic Era
Time Station
(See Trail Guide)
2nd Floor
Paleozoic Era
Time Station
(See Trail Guide)
Cenozoic Era
Time Station
(See Trail Guide)
Enter
1st Floor
Exit
PREHISTORIC
JOURNEY



GEOLOGIC TIME

It is hard, if not impossible, to imagine something as immense as 4.6 billion years. Therefore, scientists have divided Earth's history into smaller units. Each era—the largest unit of geologic time—is divided into periods. Periods, in turn, are divided into epochs. The beginning and ending dates for units of geologic time occur when the fossil record changes dramatically—usually because of the extinction of some life-forms and the appearance of others.

NOTE: The following initials for geologic time are used in the exhibit:

"B.Y.A." means **"billion years ago"**
"M.Y.A." means **"million years ago"**
"Y.A." means **"years ago"**

There are **four eras** in the geologic time scale.

An **era** is the **largest unit of geologic time.**
Eras are **subdivided into periods.**

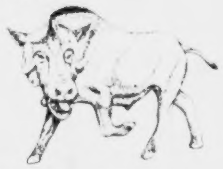
As you get closer to the present,
periods are **further divided into epochs.**

BYA
MYA
WOT YA THINK, PROFESSOR? IS IT MEANINGFUL?
YA! YA!

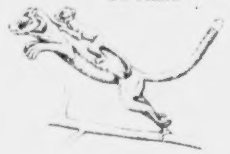
GEOLOGIC TIME SCALE

CENOZOIC ERA 65 M.Y.A.–PRESENT	**Quaternary Period** 1.6 M.Y.A.–PRESENT	Holocene Epoch 10,000 Y.A.–PRESENT
		Pleistocene Epoch 1.6 M.Y.A.–10,000 Y.A.
	Tertiary Period 65 M.Y.A.–1.6 M.Y.A.	Pliocene Epoch 5.3–1.6 M.Y.A.
		Miocene Epoch 23.5–5.3 M.Y.A.
		Oligocene Epoch 34–23.5 M.Y.A.
		Eocene Epoch 55–34 M.Y.A.
		Paleocene Epoch 65–55 M.Y.A.
MESOZOIC ERA 251–65 M.Y.A.	Cretaceous Period 145–65 M.Y.A.	
	Jurassic Period 205–145 M.Y.A.	
	Triassic Period 251–205 M.Y.A.	
PALEOZOIC ERA 545–251 M.Y.A.	Permian Period 290–251 M.Y.A.	
	Pennsylvanian Period 320–290 M.Y.A.	
	Mississippian Period 360–320 M.Y.A.	
	Devonian Period 410–360 M.Y.A.	
	Silurian Period 440–410 M.Y.A.	
	Ordovician Period 505–440 M.Y.A.	
	Cambrian Period 545–505 M.Y.A.	
PRECAMBRIAN ERA 4.6 B.Y.A.–545 M.Y.A.		

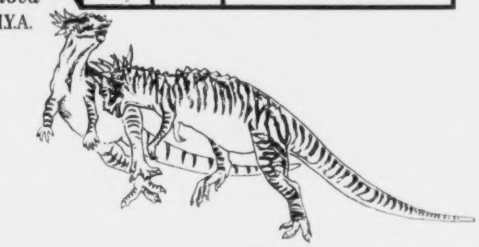
Nebraska Woodland
20 M.Y.A.



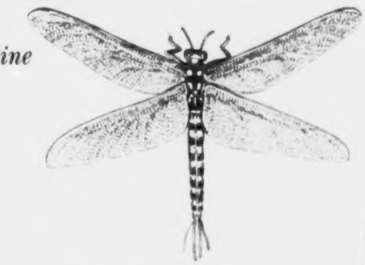
Rainforest Treetop
50 M.Y.A.



Cretaceous Creekbed
66 M.Y.A.

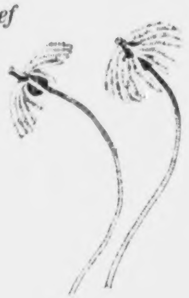


Kansas Coastline
295 M.Y.A.

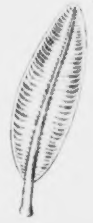


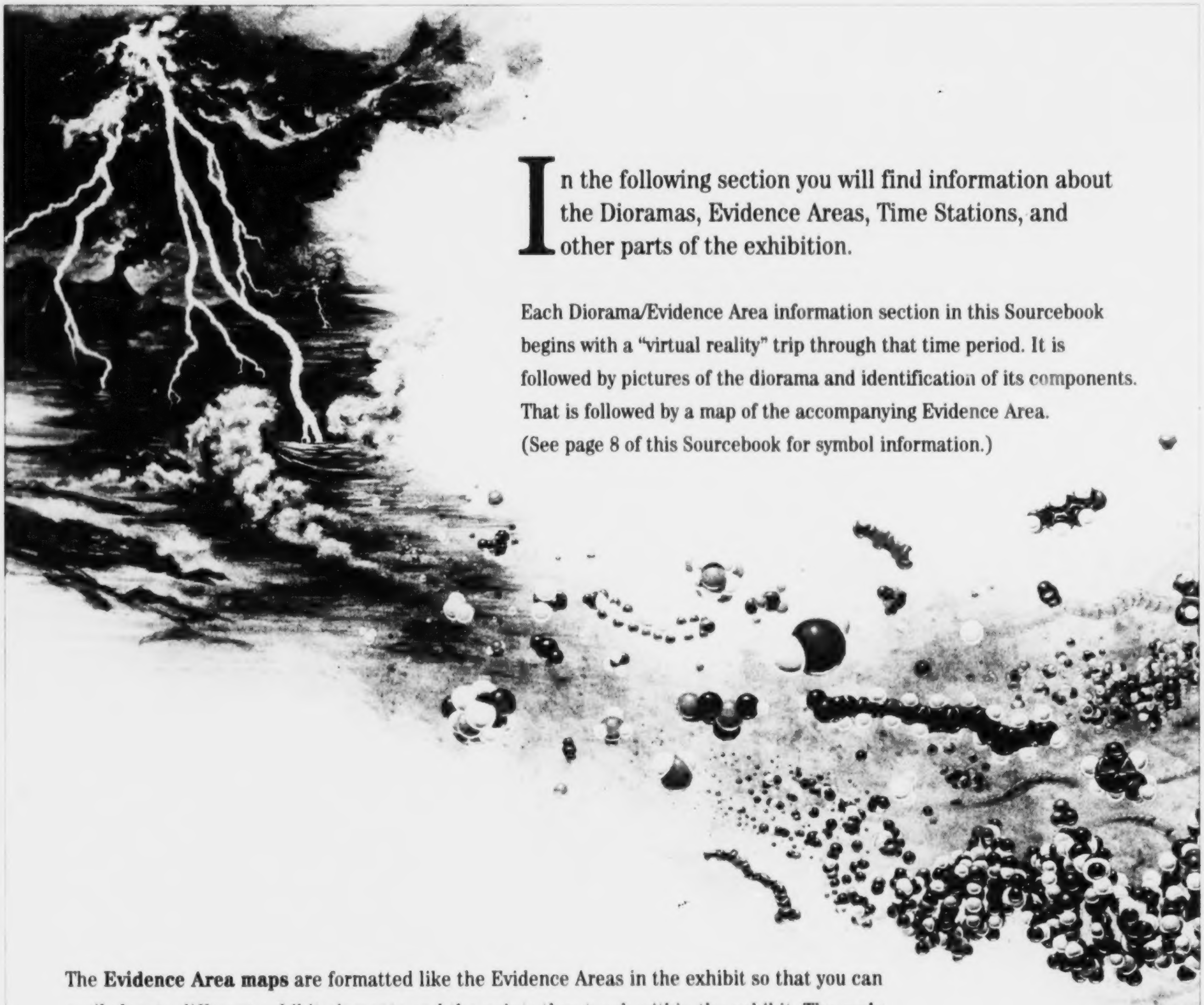
Between Two Worlds
395 M.Y.A.

Sea Lily Reef
425 M.Y.A.



Ancient Sea Floor
600 M.Y.A.





In the following section you will find information about the Dioramas, Evidence Areas, Time Stations, and other parts of the exhibition.

Each Diorama/Evidence Area information section in this Sourcebook begins with a "virtual reality" trip through that time period. It is followed by pictures of the diorama and identification of its components. That is followed by a map of the accompanying Evidence Area. (See page 8 of this Sourcebook for symbol information.)

The **Evidence Area maps** are formatted like the Evidence Areas in the exhibit so that you can easily locate different exhibit elements and the points they teach within the exhibit. The **main educational point** for each Evidence Area is given at the top of the map page. In your Evidence Area maps, the entry and exit points are connected by a dashed line with arrows indicating the direction to move through the Evidence Area. The following components are also identified:

- Exhibit cases and their related Teaching Points
- The locations of Discovery and Study Elements within the Evidence Areas
- Videos and computer interactives
- Major specimens such as large skeletons
- Other fun things to do and touch

Following each Evidence Area map, key concepts for each Evidence Area are discussed with more detail in the sections called *Additional Background Information*.

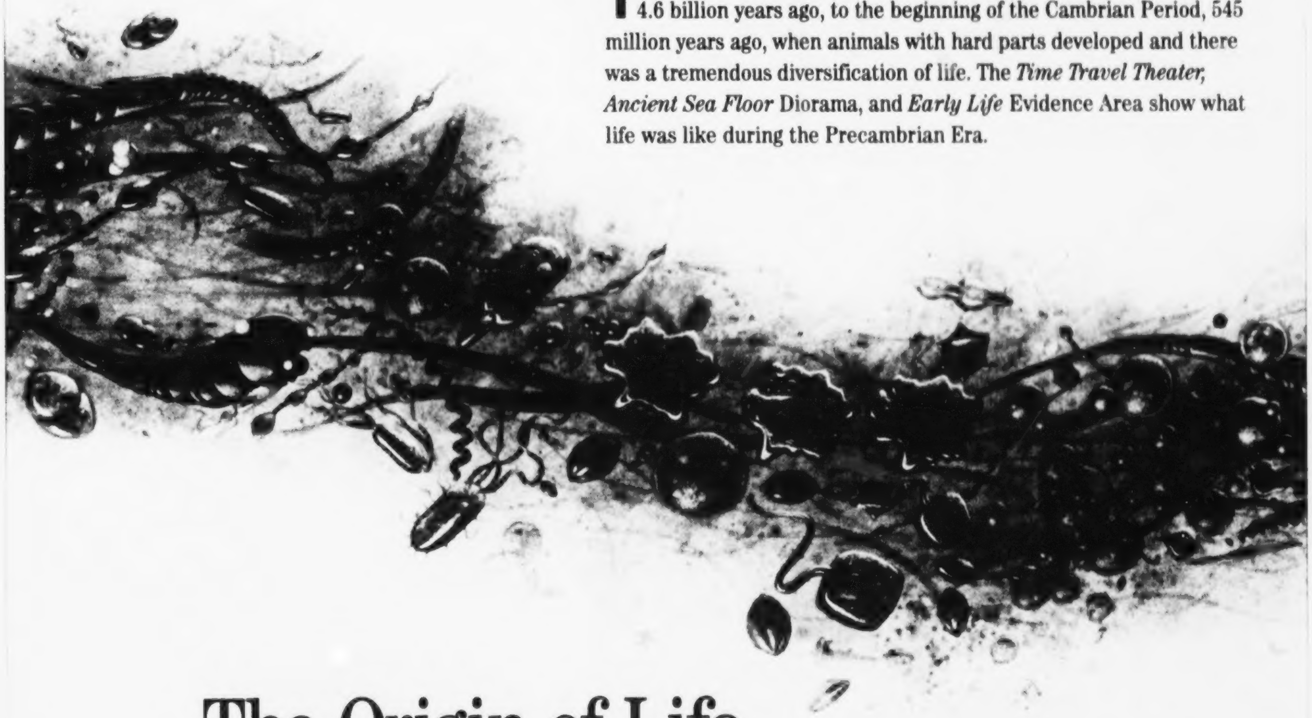
PREHISTORIC JOURNEY℠

EARLY LIFE

PRECAMBRIAN ERA

4.6 BILLION YEARS AGO – 545 MILLION YEARS AGO

The Precambrian Era spans the time from the origin of the Earth, 4.6 billion years ago, to the beginning of the Cambrian Period, 545 million years ago, when animals with hard parts developed and there was a tremendous diversification of life. The *Time Travel Theater, Ancient Sea Floor* Diorama, and *Early Life* Evidence Area show what life was like during the Precambrian Era.



The Origin of Life

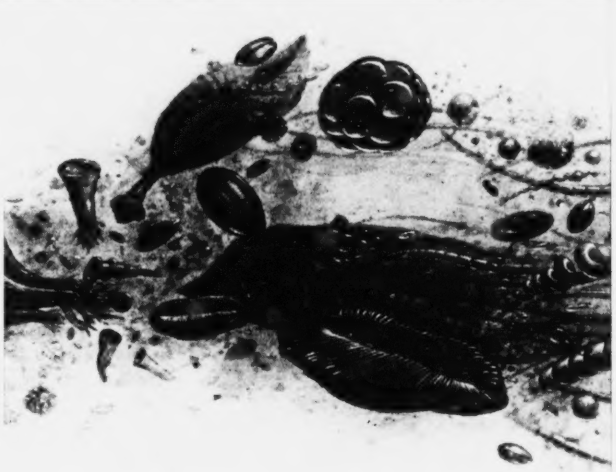
> *The proper scene for the slow brewing of life from nonlife was the early Earth. The Earth's conditions favored certain chemical combinations over others, and with the passage of time a direction was set.*
>
> Lynn Margulis and Dorion Sagan, 1993

DNA (**D**eoxyribo**N**ucleic **A**cid) is the ingredient that allows living things to reproduce. DNA is a molecule that acts like a blueprint or a computer program, directing the assembly of amino acids into protein molecules. These molecules control the growth and development of the organism. All living things have DNA.

Around the World in 4.6 Billion Years:

A VIRTUAL *PREHISTORIC JOURNEY*

Prehistoric Journey *focuses on seven critical periods of time in the Earth's history. Each of these will be explored in virtual-reality fashion. Read them to get a picture of the time period or read them to your class for fun!*



EPISODE I:

Put on your virtual reality helmet, connect your sensory glove, and prepare yourself for an epic adventure through the seas, reefs, forests, grasslands, and glaciers of the 4.6-billion-year history of Earth. You will be traveling through time and space, getting a firsthand view of the changing Earth and its many beautiful and wonderful inhabitants.

When do we start?

Now. We begin at the brand new planet Earth—4.6 billion years ago.

Is it getting hot in here?

The heat you are feeling is from the cooling Earth that is hardening from its molten state. Notice that as millions of years go by, vapor is condensing to form oceans, which cool off at night and are heated by the sun during the day. Now zoom in on those molecules composed of long, carbon-based chains. The chemical properties of those molecules are the foundation from which will emerge all the life-forms you will see in your adventure.

You are now swimming through the primordial seas of the ancient Earth—moving toward 3.5 billion years ago. Those long, coiled molecules are called deoxyribonucleic acid (DNA)—the genetic code for life.

Wow! They're splitting. Now they're attracting other atoms and molecules. They're making copies of themselves!

Right. They are reproducing on their own, a feature never seen before on this planet. This program was specially designed to highlight the diversity of life-forms that the DNA double helix will produce—given nearly 4 billion years to evolve. As you arrive at 3.5 billion years ago, the only life around now is microscopic blue-green algae (cyanobacteria).

Is that cyanobacteria over there, floating in the ocean?

Yes, and it is also living on the shore.

Where?

Zoom in on those slimy, layered mounds.

I see it now. They're literally teeming with bacteria.

Those layered mats are called stromatolites. Stromatolite colonies are the world's first ecosystems. Okay, now prepare yourself. We are going to swim a long way quickly, because life will not change a lot for most of the next 3 billion years. We will slow back down as we approach 600 million years ago—by then life will start looking different.

What a wild ride! These bacteria feel like gnats flying in my face when I ride my bike. W-W-W-Whoa! Something's wrong with my controls.

Do not adjust your controls. Life is getting larger before your eyes. These organisms on the floor of this 600-million-year-old ocean are still an enigma to scientists. They look a bit like seapens, jellyfish, and flatworms, but there are differences. Those differences may mean that they are unlike anything living today. Are they animals, plants, both, or neither? Maybe you'll study them one day and solve the mystery . . . It will be smooth swimming for a while now. You are approaching 545 million years ago. You had better brace yourself for the next 10 million years. You will be swimming through the Cambrian Explosion, a time of rapid diversification of life.

The creatures look more familiar somehow.

That is because some have heads, some have mouths, and some even have eyes.

You're right. I never thought about organisms without heads.

That's okay. They probably never thought about you, either.

Very funny. Things really are changing around here.

The number of different kinds of living things is increasing at a dizzying pace—mollusks, sponges, worms, trilobites, brachiopods, animals with spinal cords . . . The world will never be the same, but who would want it to be?

Whew! Hey, can we take a break? Swimming through 4 billion years is exhausting.

All right. The program will pause now so that you can rest because the next leg of our journey promises more excitement and adventure as we continue our exploration of life's extraordinary history.

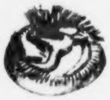
EPISODE II: Diving into Diversity

Rebecca Smith, Earth Sciences Educator

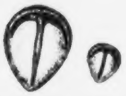
©Reprinted from *Museum Quarterly*, 1994 Summer Issue

FIRST MULTICELLULAR LIFE

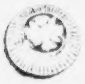
Ediacara Hills, South Australia
Precambrian Era, 600 million years ago



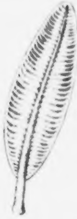
Tribrachidium heraldicum



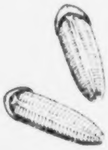
Parvancorina minchami



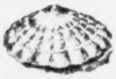
Ediacaria flindersi



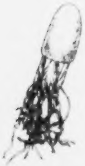
Charniodiscus arboreus



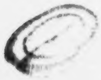
Spriggina floundersi



Mawsonites spriggi

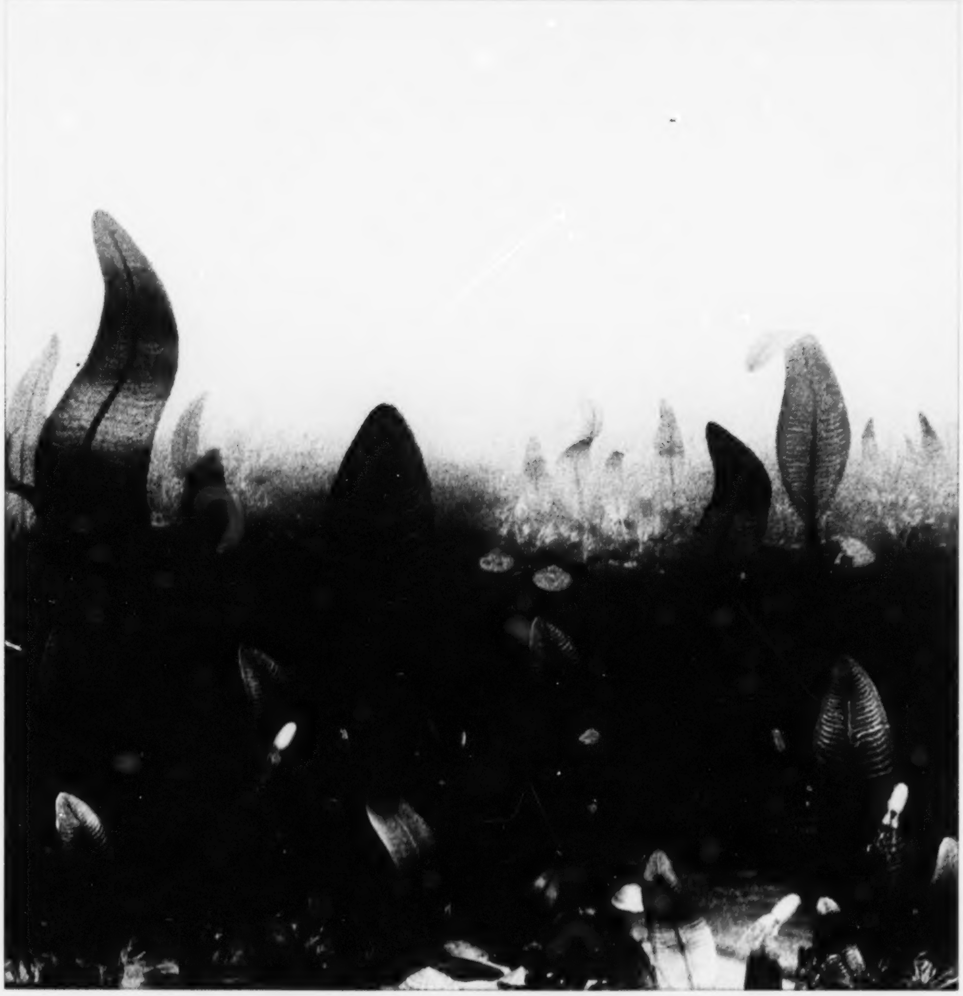


Kimberella quadrata



Dickinsonia costata

ANCIENT SEA FLOOR DIORAMA



EARLY LIFE

Ancient Sea Floor

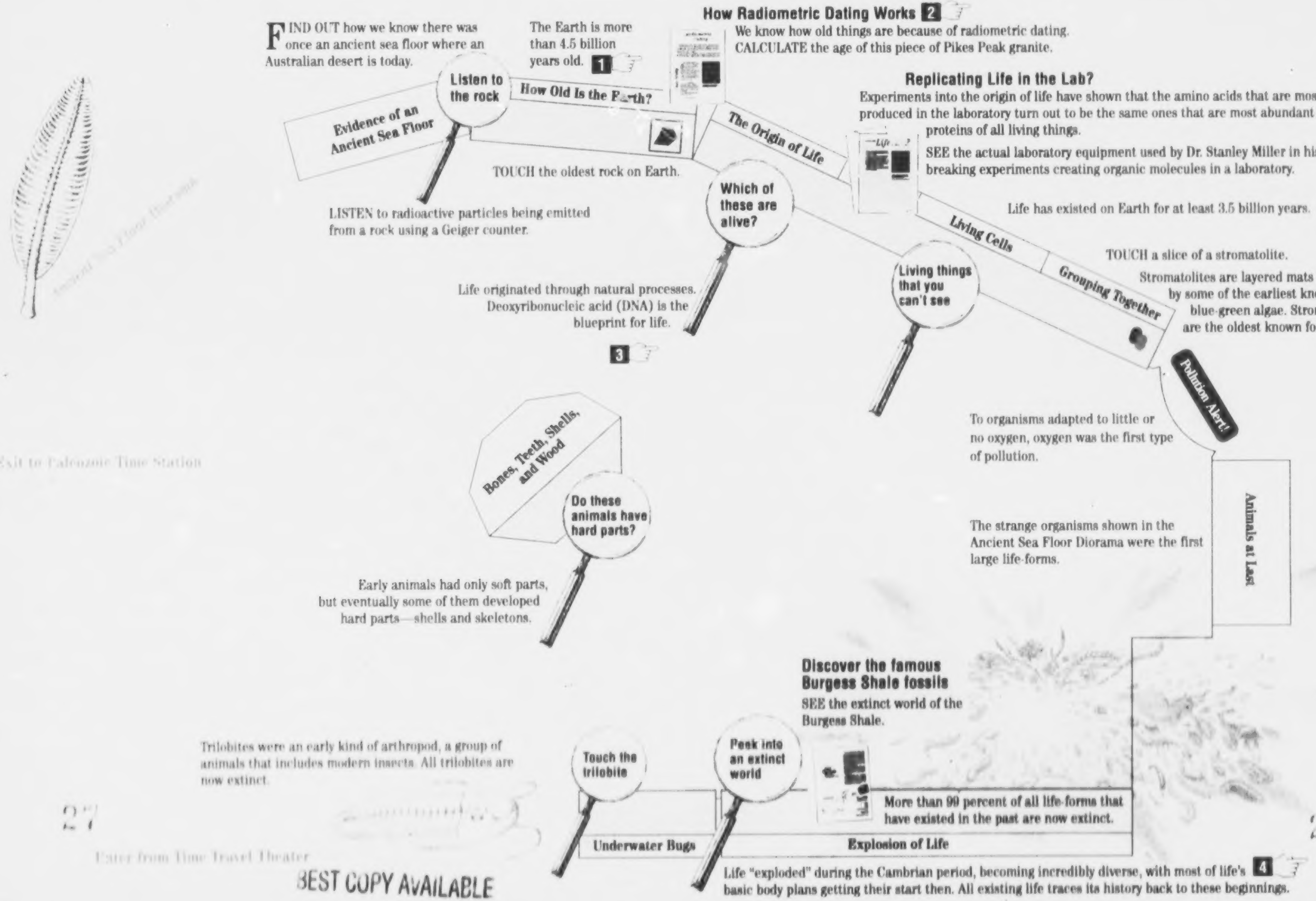
600 million years ago

THE FIRST LARGE LIFE-FORMS ARE LIVING ON THE BOTTOM OF this ancient sea. They are made of many cells, and are much bigger than all earlier life, but they don't interact with each other at all.

It has been about 3 billion years since life began.

1. *EARLY LIFE* EVIDENCE AREA MAP

The first living things were simple and lived underwater. Then, in an explosion of life, many new kinds of living things evolved and populated the seas.



Ancient Sea Floor Diorama
Evidence of an Ancient Sea Floor
Listen to the rock
How Old Is the Earth?
The Origin of Life
Which of these are alive?
Living Cells
Living things that you can't see
Grouping Together
Pollution Alert!
Animals at Last
Bones, Teeth, Shells, and Wood
Do these animals have hard parts?
Touch the trilobite
Peek into an extinct world
Underwater Bugs
Explosion of Life
Exit to Paleozoic Time Station
Enter from Time Travel Theater

FIND OUT how we know there was once an ancient sea floor where an Australian desert is today.

The Earth is more than 4.5 billion years old. **1** ☞

TOUCH the oldest rock on Earth.

LISTEN to radioactive particles being emitted from a rock using a Geiger counter.

How Radiometric Dating Works **2** ☞

We know how old things are because of radiometric dating. CALCULATE the age of this piece of Pikes Peak granite.

Replicating Life in the Lab?

Experiments into the origin of life have shown that the amino acids that are most easily produced in the laboratory turn out to be the same ones that are most abundant in the proteins of all living things.

SEE the actual laboratory equipment used by Dr. Stanley Miller in his groundbreaking experiments creating organic molecules in a laboratory.

Life has existed on Earth for at least 3.5 billion years.

TOUCH a slice of a stromatolite.

Stromatolites are layered mats formed by some of the earliest known life—blue-green algae. Stromatolites are the oldest known fossils.

Life originated through natural processes. Deoxyribonucleic acid (DNA) is the blueprint for life.

3 ☞

To organisms adapted to little or no oxygen, oxygen was the first type of pollution.

The strange organisms shown in the Ancient Sea Floor Diorama were the first large life-forms.

Early animals had only soft parts, but eventually some of them developed hard parts—shells and skeletons.

Discover the famous Burgess Shale fossils

SEE the extinct world of the Burgess Shale.

Trilobites were an early kind of arthropod, a group of animals that includes modern insects. All trilobites are now extinct.

More than 99 percent of all life-forms that have existed in the past are now extinct.

Life "exploded" during the Cambrian period, becoming incredibly diverse, with most of life's basic body plans getting their start then. All existing life traces its history back to these beginnings. **4** ☞

BEST COPY AVAILABLE

EARLY LIFE

Additional Background Information

1

HOW OLD IS THE EARTH—

RADIOMETRIC DATING

How do scientists know how old things are? How is it that we know that dinosaurs lived more than 65 million years ago, or that the Earth is about 4.6 billion years old? These statements are pretty bold, considering we have been looking at the evidence for only about 100 years.

One of the most reliable methods to estimate the age of rocks is **radiometric dating**. The rocks used in radiometric dating are igneous rocks (rocks cooled from a molten state). The radiometric "clock" is set—and reset—each time molten rocks cool and crystals begin to grow. Mineral crystals are made up of fairly constant portions of elements (the basic types of matter in purest form).

Each element can come in different forms, or isotopes, depending on whether it has extra electrons or neutrons or needs one of these atomic particles. Some combinations in some elements are unstable and are termed "radioactive," because when they gain or release particles, they emit energy in the form of radiation. The loss of energy is often accompanied by the loss of a particle or the change in charge of a neutron, and this results in a new element being formed. The element doing the emitting is called the "Parent" and the resulting element is called the "Daughter" or "Product." Since scientists have determined precisely how fast the **parent elements** (the original elements) decay into their **daughter elements** (the product elements resulting from decay), they can tell the age of the rocks by looking at how much parent and daughter elements are contained in a rock.

Fossils usually aren't found in igneous rocks, but in sedimentary rocks. Scientists look for igneous rocks above and below fossil layers to obtain dates that "sandwich" the age of the fossils.

IMPORTANT

Radiometric dating is sometimes confused with **radiocarbon** (carbon 14) **dating**. Radiocarbon dating is *only one type* of radiometric dating. Radiocarbon dating is an effective method for dating original organic material under 50,000 years old—it is not used to date things millions of years old because carbon 14 decays too rapidly (it has a short half-life—approximately 5,730 years). There are many other types of radiometric isotopes that are commonly used to date rocks, like rubidium 87 (rubidium-strontium dating), thorium 232 (thorium-lead dating), and potassium 40 (potassium-argon dating). **With their respective half-lives of approximately 48.6 billion years, 14.0 billion years, and 1.3 billion years, these methods can date rock layers that are billions of years old.**

2

HOW RADIOMETRIC DATING WORKS—

THE BASICS

Every radioactive element has a **half-life**, the amount of time it takes for one-half of the current amount of the element to decay. Uranium 235 has a half-life of 700 million years. If you had 1 kilogram of uranium 235, the parent element, sitting in a box, and then looked inside after 700 million years, you would have 0.5 kilogram of uranium 235 left inside the box—and about 0.5 kilogram of lead 207, the daughter element. If you waited another 700 million years, then looked inside the box, you would find that half of the uranium 235 that remained after the first 700 million years would have decayed. In other words, there would now be 0.25 kilogram of uranium 235, and about 0.75 kilogram of lead 207. By using this same line of reasoning, a scientist could look inside the box at any time, measure the amount of uranium 235 and lead 207, and calculate how many years must have gone by since the box started with 100 percent uranium 235.

You may have wondered why after the first 700 million years there was exactly 0.5 kilogram of uranium 235, but only *about* 0.5 kilogram of lead 207. The reason is because each single atom of uranium 235 decays into a single atom of lead 207. But an atom of lead 207 actually weighs *less* than an atom of uranium 235. So the amount of lead 207 left in the box is *less* than 0.5 kilogram. The lighter weight is due to the loss of small particles that were emitted and lost from the atom, or radiated away, during the decay process (hence the name—**radioactive**). Scientists take this difference of weight into account when doing their calculations.

In the real world, scientists must consider a number of other factors to make accurate estimates of the date of rocks. Was there any lead 207 in the rock to start with? Did any uranium 235 or lead 207 erode away? Might something else have happened to the rock over the years to alter the amounts of parent and daughter elements in the rock? By checking many samples of rock, dating the same rock with other pairs of parent and daughter elements that it might happen to contain, and using statistical methods, scientists can often make a very good estimate of the date of the rock.

EARLY LIFE

Additional Background Information

3 *THE ORIGIN OF LIFE—*

All living things on Earth share three common fundamentals: first, the use of carbon-based (organic) molecules; second, a self-replicating blueprint (DNA, or the more simple, single-stranded RNA); and third, metabolic activity. Viruses qualify for the first two, but not the last. The Time Travel Theater in *Prehistoric Journey* presents the idea that life originated on Earth through the natural processes of inorganic gases, water, and energy.

When we speak of the origin of life, the questions really are How did DNA/RNA come about? and What came before?

In the early 1950s, Stanley Miller and Harold Urey mixed hydrogen, methane, ammonia, and water vapor (the gasses that in theory made up the early Earth's atmosphere) together and added electrical charges to simulate lightning. The results were unexpected and eye-opening: Amino acids, the basic building blocks of proteins, and other potential biological molecules were formed. Miller did not "create" life, but he did find some of its basic building blocks in the "prebiotic soup" he cooked up. Scientists now think that there was less hydrogen than Urey postulated, but Miller's findings have been corroborated by the discovery of a meteorite in Murchison, Australia, which contains the same amino acids, even in the same proportions, that Miller found in his "soup," indicating that these compounds were created in the early solar system in abiotic chemical reactions.

Recipe for Life

carbon
sulphur
nitrogen
hydrogen
oxygen
phosphorus

Mix together in a warm, moist environment.

Dry out occasionally.

Add time and energy.

Allow to combine in orderly, patterned ways.

The **components** of RNA's nucleotides (the four building blocks of life, adenine(A), guanine(G), cytosine(C), and uracil(U)) are easily synthesized in the laboratory. DNA has A, G, C, and U is replaced by thymine(T). DNA only stores genetic information; RNA carries out the functions of life. While it is easy to synthesize the components that make up nucleotides, efforts to try to produce A, G, C, T, and U from "soups" similar to Miller's are still ongoing (A and G have been made, but there is more difficulty with C and U).

4 *EXPLOSION OF LIFE—*
CLASSIFYING LIVING THINGS

Scientists have divided living things into five **kingdoms**, the most encompassing unit in the biological classification system. The five kingdoms of life on Earth are

Monera—The monera, formerly called prokaryotes, consist mainly of bacteria (single-celled organisms with no nucleus).

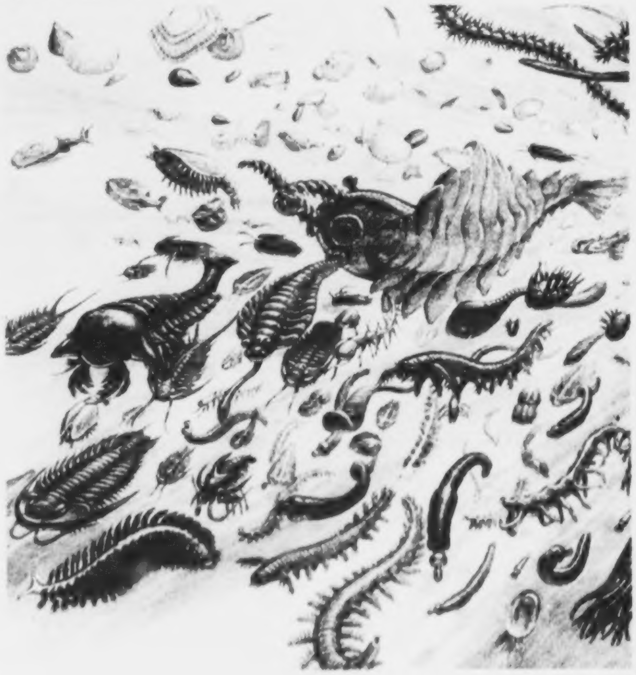
Protoctista—The protoctista are aquatic, single-celled organisms that have nucleated cells and reproduce sexually. They include dinoflagellates, paramecia, amoebas, and slime molds.

Fungi—The fungi, like mushrooms, absorb their food from decaying organic matter.

Animalia—Animals.

Plantae—Plants.

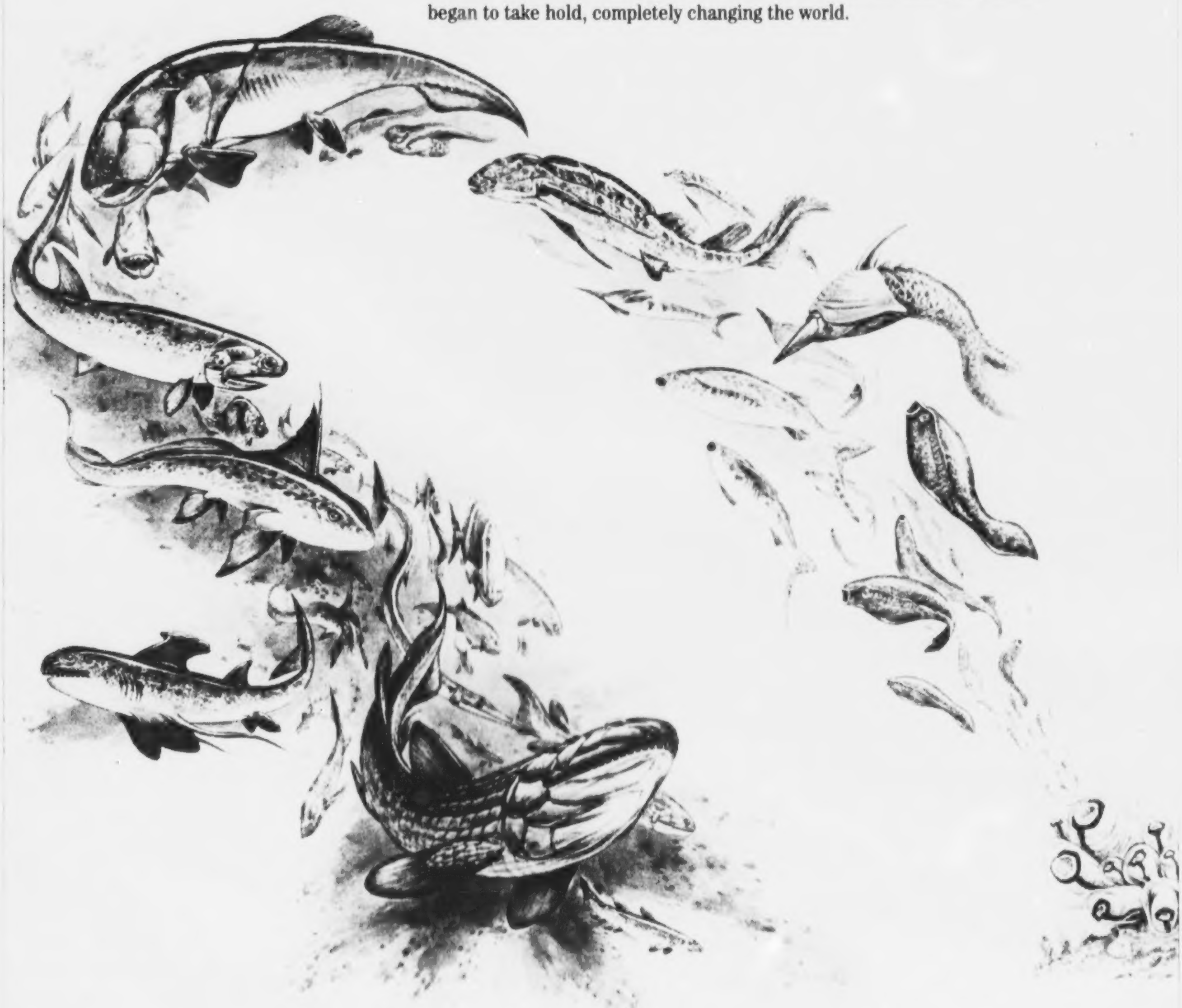
Within each kingdom are smaller groups called phyla (the singular is **phylum**). Most of the major phyla within the animal kingdom first appeared on Earth during the Cambrian Period, as explained in the *Explosion of Life* panel. Within each phylum, there are increasingly smaller and less encompassing categories, including **class, order, family, genus,** and **species**. Organisms are usually denoted by their genus and species name, like *Homo sapiens* and *Tyrannosaurus rex*.



PALEOZOIC ERA

545 – 251 MILLION YEARS AGO

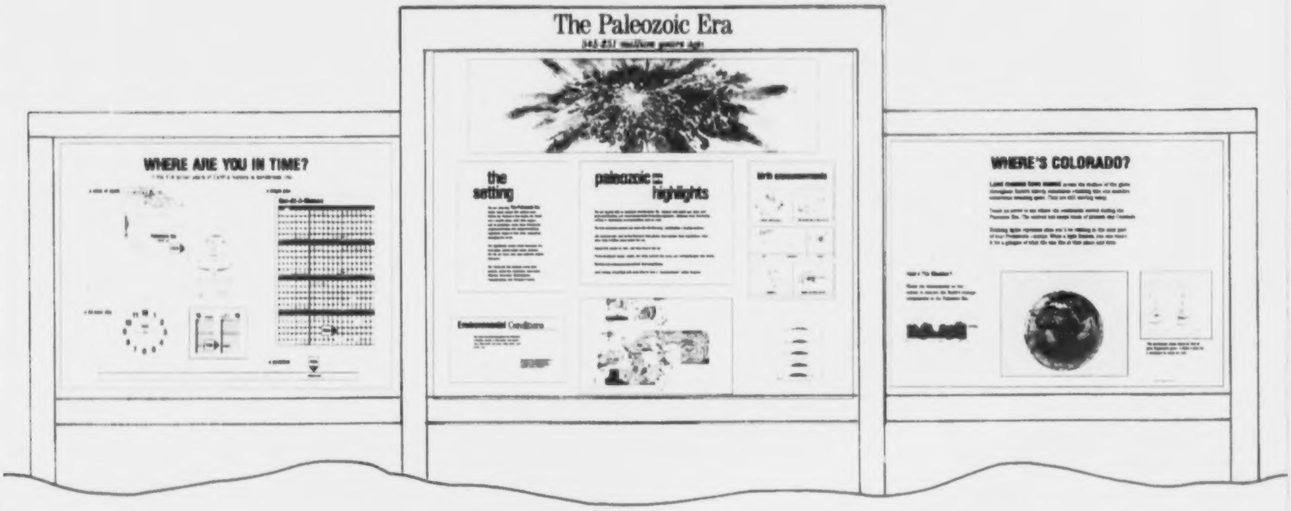
The Paleozoic Era lasted almost 300 million years. Before the Paleozoic Era began, the Earth was a hostile place—with little oxygen and no protective ozone layer. Eventually, oxygen-producing and oxygen-breathing organisms began to take hold, completely changing the world.



The significant events of the Paleozoic Era took place mostly underwater—because life did not move onto land until the middle Paleozoic.

The Paleozoic Era includes seven time periods, called the Cambrian, Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, and Permian Periods.

PALEOZOIC TIME STATION


The Paleozoic Era
WHERE ARE YOU IN TIME?
the setting
paleozoic highlights
birth announcements
Environmental Conditions
WHERE'S COLORADO?

PALEOZOIC ERA HIGHLIGHTS

The era opened with an explosion of underwater life. Animals with shells and other hard parts proliferated, and every known basic body plan appeared. Life-forms went from being solitary to interacting in communities, such as reefs.

The first predators evolved and went after the first prey, establishing a familiar pattern.

Life ventured onto land for the first time—first plants, then insects, then amphibians—after more than 3 billion years under the sea.

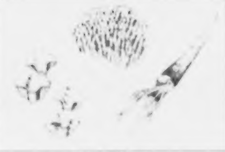
Insects first moved on land, and then took to the air.

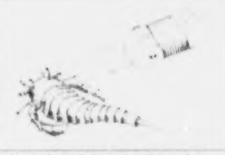
Plants developed leaves, seeds, and roots; evolved into trees; and eventually grew into forests.

Reptiles and protomammals evolved from amphibians.

Land masses all collided with each other to form a "supercontinent" called Pangaea.

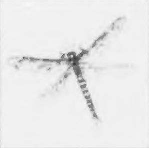
birth announcements

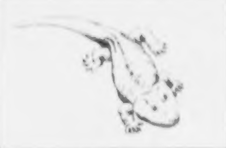

Animals with hard parts

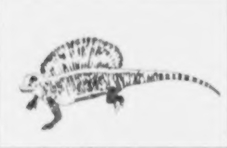

Animals with legs, heads, and eyes

Fish

Land plants


Insects


Amphibians


Reptiles and Protomammals

BEST COPY AVAILABLE

BREAKING UP

PALEOZOIC TIME STATION
ADDITIONAL INFORMATION

HERE'S COLORADO?—PLATE TECTONICS

IS SUCH A HARD THING

In 1912, Alfred Wegner proposed the theory of continental drift. He was the first to conduct a thorough analysis of the idea (though the first map showing continental drift was made in 1854) that at one time all the continents were attached, forming a supercontinent called **Pangaea**. Over millions of years, the continents drifted apart to reach their present positions. Today, this theory is more inclusively called **plate tectonics** and is supported by fossil, geological, and oceanographic evidence.

Plate tectonics is the very slow, large-scale, continual movement of the plates in the Earth's crust. This movement has caused geological events such as earthquakes, volcanoes, and mountain-building. Most of the world's volcanoes and earthquakes occur along plate borders.

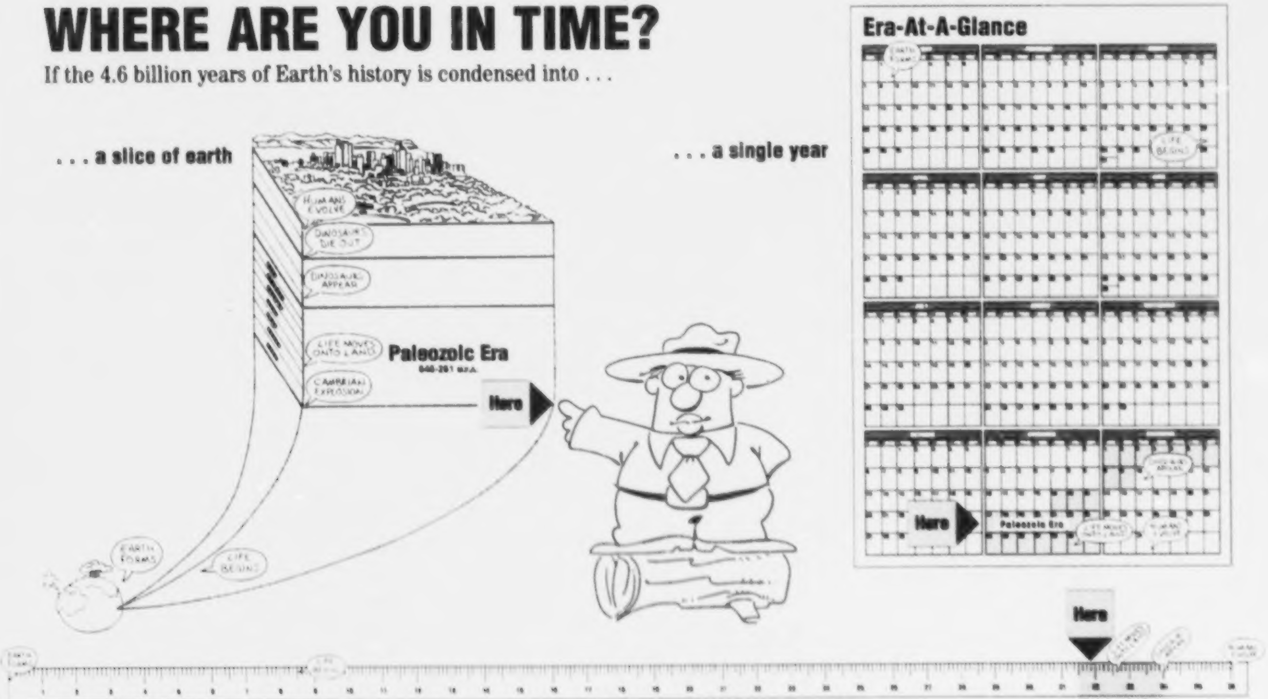
The Earth's surface is fragmented into 20 tectonic plates. The continents are the top portions of some of these independently moving plates. Seven of the plates, such as the Pacific Ocean Plate and the Eurasian Continental Plate, are enormous, underlying entire oceans or continents. The remaining 12 plates are much smaller. There are four types of plate movements:

1. Some plates are pulling apart, often because the sea floor is spreading.
2. Some plates are pushing against each other, crumpling the Earth's crust.
3. Some plates are sliding past each other.
4. In some places, one plate is sliding beneath another.

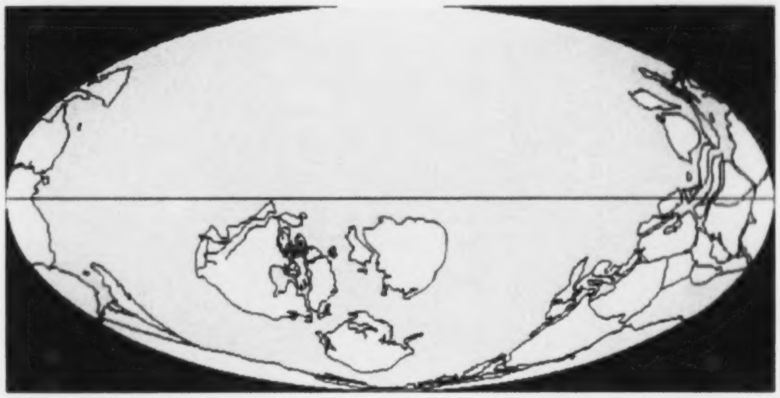
The **Where's Colorado?** plate tectonics computer touch-screen interactive allows students to move the continents through time and get a glimpse of the next stops on their *Prehistoric Journey*.

WHERE ARE YOU IN TIME?

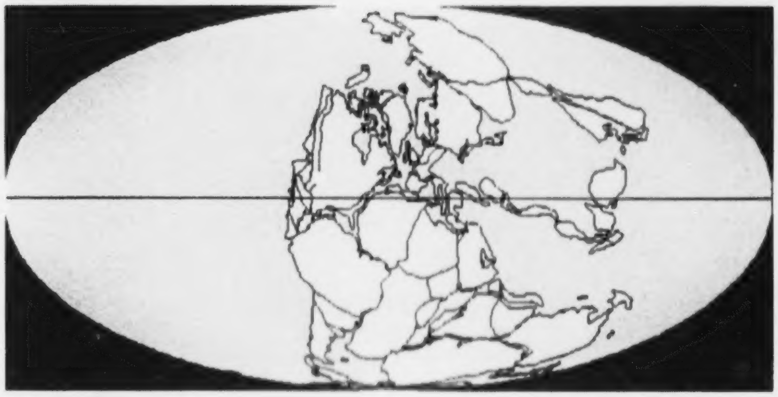
If the 4.6 billion years of Earth's history is condensed into . . .


. . . a slice of earth
HUMANS EVOLVE
DINOSAURS DIE OUT
DINOSAURS APPEAR
LIFE MOVES ONTO LAND
Paleozoic Era
CAMBRIAN EXPLOSION
Here
EARTH FORMS
LIFE BEGINS
. . . a single year
Era-At-A-Glance
EARTH FORMS
LIFE BEGINS
Here
Paleozoic Era
LIFE MOVES ONTO LAND
DINOSAURS APPEAR
HUMANS EVOLVE
Here
Paleozoic Era

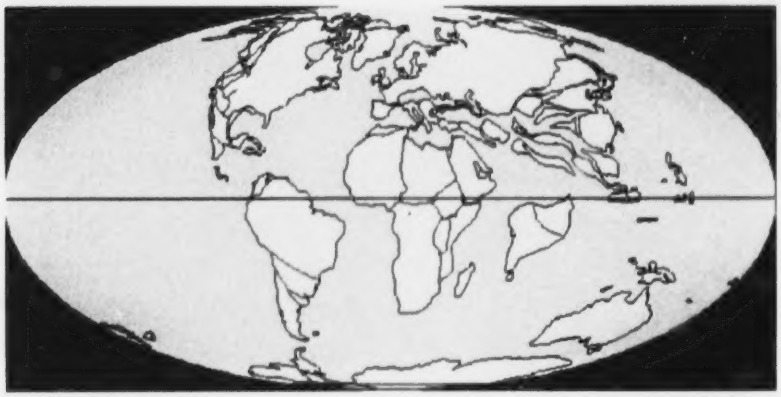
Throughout Earth's history, land masses have moved across the surface of the globe, sometimes crashing into or under one another, sometimes breaking apart. They are still moving today.



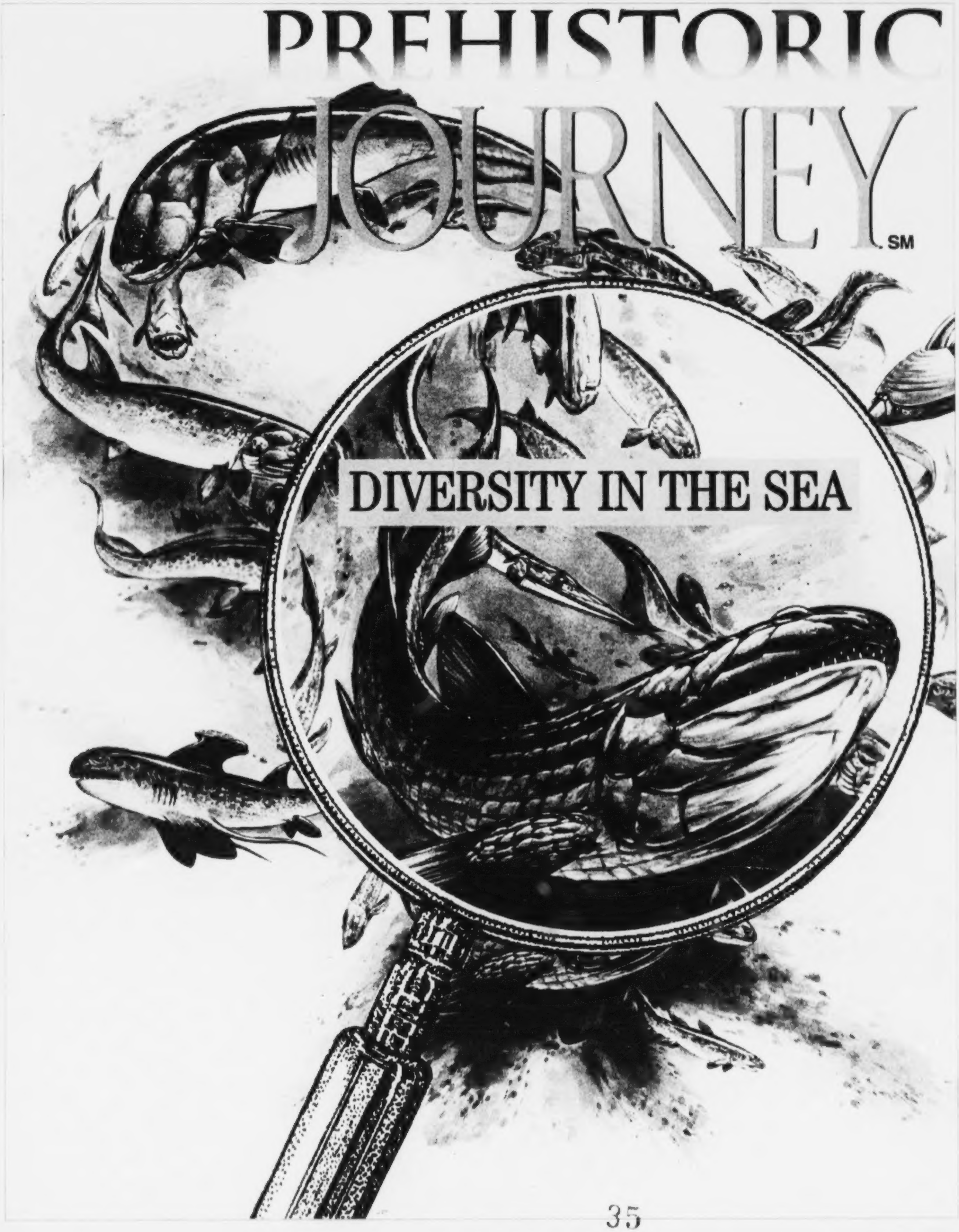
PALEOZOIC
545 M.Y.A.



MESOZOIC
251 M.Y.A.



CENOZOIC
65 M.Y.A.


PREHISTORIC
JOURNEY SM
DIVERSITY IN THE SEA
35

Around the World in 4.6 Billion Years:

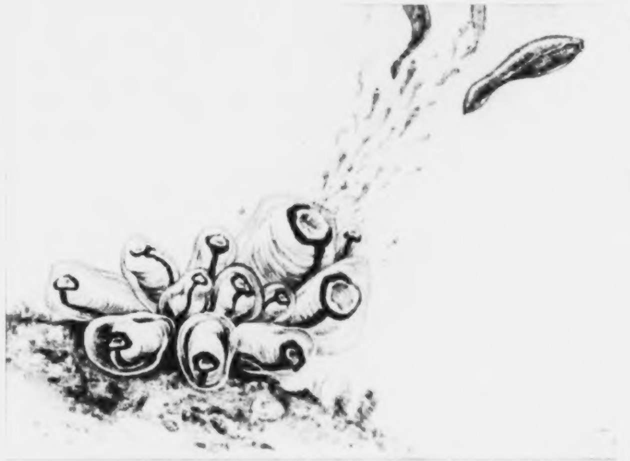
A VIRTUAL *PREHISTORIC JOURNEY*

EPISODE II:

Diving into Diversity

Now that you're wired in to the virtual reality program again, we can resume our trip through time where we left off.

Hold on a second. You're not going to plunge me back into the middle of that Cambrian Explosion, are you? Swimming through all those new sponges, worms, mollusks . . . Those brachiopod shells hurt, and those trilobites with spines sticking out of them could poke my eye out! Couldn't you start me off with a little less of a jolt—some nice, tranquil, warm lagoon or something? Say, sometime after the end of the Cambrian Explosion?



Scanning . . . How about Racine, Wisconsin, Silurian Period, 425 million years ago?

Wisconsin? I said a nice, quiet lagoon, not Lake Michigan! And hey, I said warm, as in tropical.

425 million years ago North America was near the equator and much of the continent was under warm, shallow, tropical seas. You are now swimming above a reef teeming with life.

Wow, this is really beautiful. This reef is as full of different kinds of living things as the one I snorkeled around in Australia on my vacation. What are those flowers waving on the bottom called?

Those are crinoids. People sometimes call them sea lilies, but they are not flowers, they are not even plants. They are animals, with more in common with whales than lilies.

Hold it right there, buster. Just because you're a know-it-all computer, don't think you can put any ridiculous idea over on me.

Then look closer and see for yourself. You are familiar with baleen?

Sure. It's that bristle-like stuff in some whales' mouths that they use to strain huge amounts of tiny organisms from the sea for food.

Okay, A+ on that pop quiz. Now, for extra credit, zoom in on those feather-like projections and tell me what the crinoids use them for.

Oh, I see. They're straining tiny things out of the water and digesting them. I guess they really are animals that have something in common with whales.

They are echinoderms—like sand dollars, sea stars, and sea urchins. Crinoids are very abundant here in the ancient sea, but are much more scarce in the modern oceans you are familiar with.

There's something fishy about this reef. I can't quite put my finger on it . . . I know—where are all the fish that swim around reefs eating everybody else?

The dominant predators of this ancient reef are not fish, they are those large squid-like animals with shells, swimming near the reef searching for animals to eat. They are cephalopods, like their modern relatives, squid, octopus, and the chambered nautilus.

Those pointy ones look like little rockets zooming around the reef.

Good analogy. Cephalopods swim by jet propulsion—they suck in water and eject it in the direction opposite to the one in which they're moving. They are also the most intelligent of all invertebrates—and they are carnivores. For example, squids seize their prey with tentacles covered with suction cups and crush them with strong, sharp beaks.

Jet-propelled, tentacled, prey-crushers—Oh my! And I thought Jaws *was scary.*

So would the cephalopods. The evolution and proliferation of fish resulted in cephalopods being preyed upon by a more effective predator—sharks!

In this ancient sea, fish are the closest thing to me, right?

Correct—that is, if you consider yourself to be a vertebrate. Fish are the first vertebrates, or animals with backbones, and are the ancestors of all living vertebrates.

Where did fish come from?

They may have evolved from tunicates, or sea squirts. Tunicates "squirt" their larvae into the water. These larvae have a primitive type of spinal cord that disappears when they become adults, making them the closest thing to a primitive vertebrate.

What? Larvae in my family tree? Well, I guess it's a few hundred million years too late to call an extermina . . .

BE VERY STILL. As we approach 395 million years ago, my program is anticipating an encounter with a eurypterid.

A you-ripped-your-what? Oh my . . . aaaaaaaaaaah! That giant claw's about to turn me into a sea squirt. Stop the program!

EPISODE III: Amphibious Landing on the Beaches of Wyoming

Rebecca Smith, Earth Sciences Educator
®Reprinted from *Museum Quarterly*, 1994 Fall Issue

SEA LILY REEF DIORAMA

DIVERSITY IN THE SEA

Sea Lily Reef

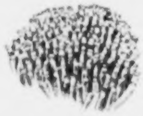
425 million years ago

THE OCEANS ARE NOW FILLED WITH LIFE. THE CREATURES OF THIS colorful reef depend on each other for shelter and food. The main predators are ancient relatives of squid and octopus—but with shells—that swim near the reef in search of prey.

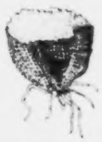
It has been 175 million years since the first multicellular life lived on the ancient sea floor.

EARLY CORAL REEF

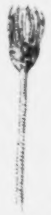
Racine, Wisconsin
Middle Silurian Period,
425 million years ago



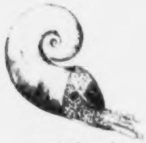
rugose coral
Pycnostylus guelphensis



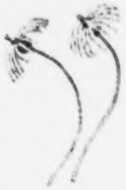
bryozoan
Fenestrellina sp.



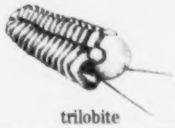
crinoid
Eucalyptocrinites crassus



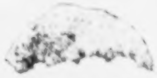
cephalopod
Uranoceras hercules



crinoid
Calliocrinus cornutus

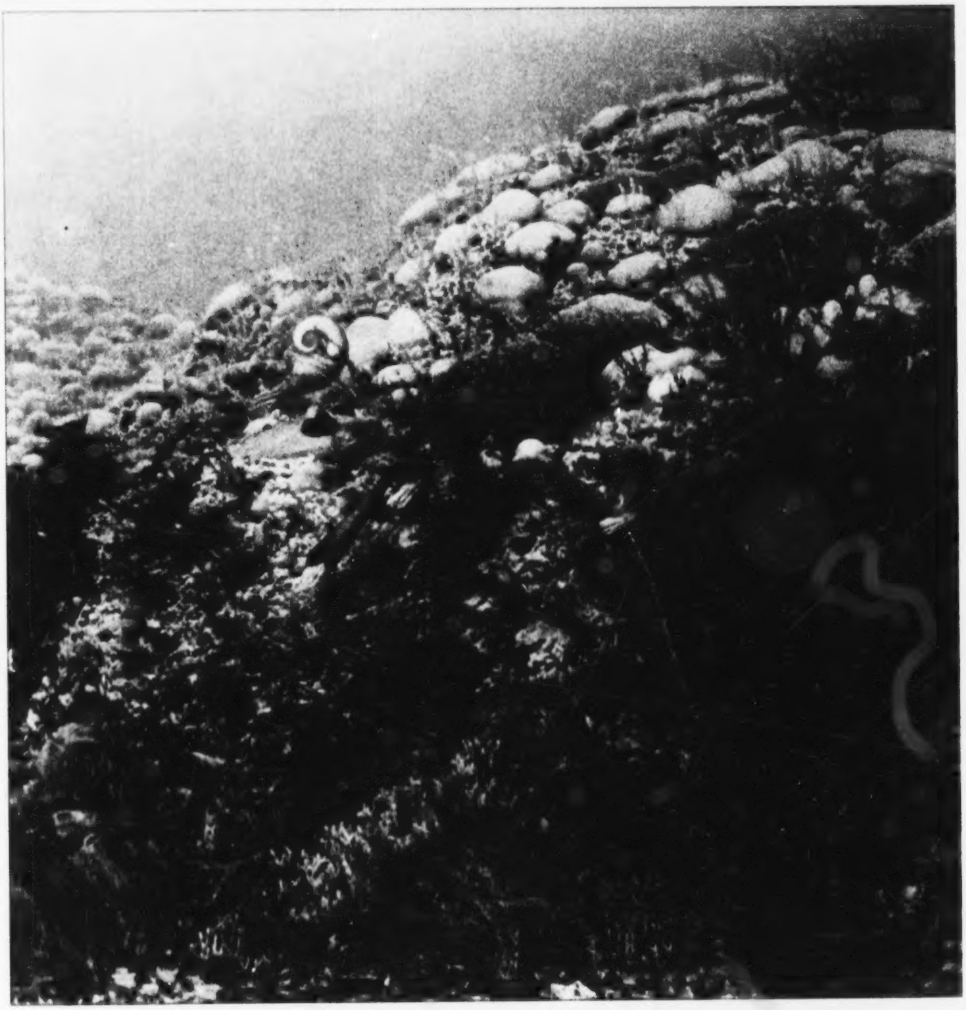


trilobite
Gravicalymene celebra

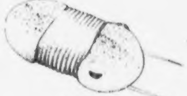


stromatoporoid
Clathrodictyon vesiculosum

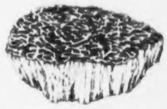
SEA LILY REEF DIORAMA



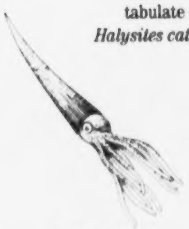
DIVERSITY IN THE SEA



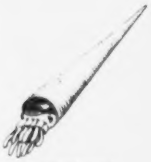
trilobite
Bumastus ioxus



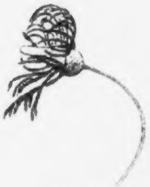
tabulate coral
Halysites catenularia



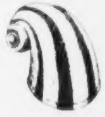
cephalopod
Kionoceras cancellatum



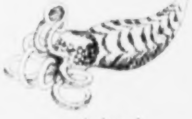
cephalopod
Dawsonoceras annulatum



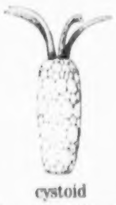
crinoid
Siphonocrinus nobilis



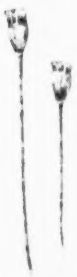
gastropod
Platyceras niagarensis



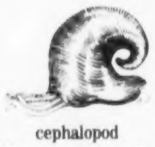
cephalopod
Amphicyrtoceras orcas



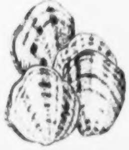
cystoid
Holocystites alternatus



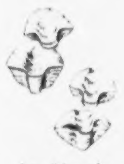
blastoid
Troostocrinus subcylindricus



cephalopod
Phragmoceras nestor



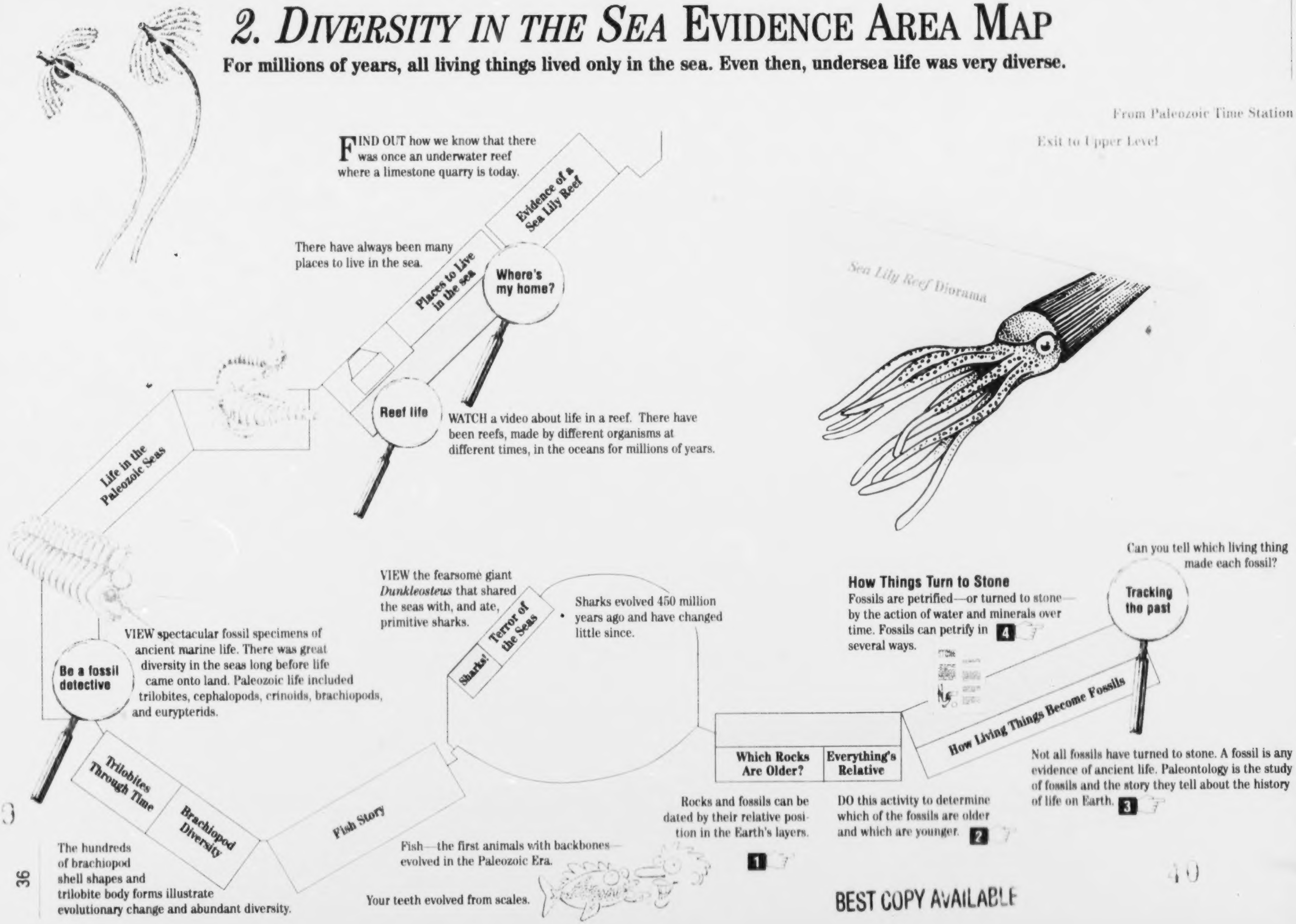
brachiopod
Pentamerus oblongus



brachiopods
Eospirifer radiatus

2. *DIVERSITY IN THE SEA* EVIDENCE AREA MAP

For millions of years, all living things lived only in the sea. Even then, undersea life was very diverse.


From Paleozoic Time Station
Exit to Upper Level
Evidence of a Sea Lily Reef
Places to Live in the Sea
Where's my home?
Sea Lily Reef Diorama
Reef life
Life in the Paleozoic Seas
Be a fossil detective
Trilobites Through Time
Brachiopod Diversity
Fish Story
Sharks!
Terror of the Seas
Which Rocks Are Older?
Everything's Relative
How Living Things Become Fossils
Tracking the past

FIND OUT how we know that there was once an underwater reef where a limestone quarry is today.

There have always been many places to live in the sea.

WATCH a video about life in a reef. There have been reefs, made by different organisms at different times, in the oceans for millions of years.

VIEW spectacular fossil specimens of ancient marine life. There was great diversity in the seas long before life came onto land. Paleozoic life included trilobites, cephalopods, crinoids, brachiopods, and eurypterids.

VIEW the fearsome giant *Dunkleosteus* that shared the seas with, and ate, primitive sharks.

Sharks evolved 450 million years ago and have changed little since.

How Things Turn to Stone

Fossils are petrified—or turned to stone—by the action of water and minerals over time. Fossils can petrify in several ways. **4**

Can you tell which living thing made each fossil?

Not all fossils have turned to stone. A fossil is any evidence of ancient life. Paleontology is the study of fossils and the story they tell about the history of life on Earth. **3**

Rocks and fossils can be dated by their relative position in the Earth's layers. **1**

DO this activity to determine which of the fossils are older and which are younger. **2**

The hundreds of brachiopod shell shapes and trilobite body forms illustrate evolutionary change and abundant diversity.

Fish—the first animals with backbones—evolved in the Paleozoic Era.

Your teeth evolved from scales.

BEST COPY AVAILABLE

DIVERSITY IN THE SEA

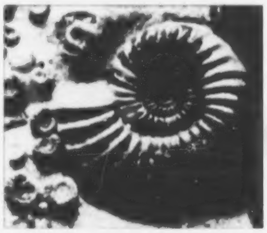
Additional Background Information

1 *WHICH ROCKS ARE OLDER?—* DATING FOSSILS AND ROCK LAYERS

A desktop is an example of geologic laws in action. As layers of mail and paperwork pile up, the first pieces deposited are buried below an ever increasing burden of more recent papers. A journey to the bottom of the stack reveals a chronological history of past activities—the copying machine memo from last Tuesday is on top of last month's PTA notes. At the bottom of the pile is a welcome-back card from the beginning of the school year. The items at the bottom are older, and items toward the top of the pile are progressively younger. This is an example of the geologic **Principle of Superposition**. The first layers of rock and sediment are covered by more recent layers of rock and sediment. Geologist and paleontologists use this principle to place rock formations and fossils into a chronology or **relative** time scale.

2 EVERYTHING'S RELATIVE

Comparing the age of rock layers in one place with rock layers from another place requires an understanding of the **Principle of Faunal Succession**. In the mid-nineteenth century, William Smith, an engineer, speculated that similar sets of fossils (the fauna) found in rock strata from different locations around the world indicated that the strata were similar in age. If two rock formations contained a particular type of ammonite, one could conclude that both layers were from the same time period. This idea allows geologists and paleontologists to use specific indicator fossils, fossils unique to particular periods of geologic history, to place rock formations into a relative chronology. Have your students try their hands at relative dating with the *Everything's Relative* interactive. To go into even greater depth on this subject, also check out *How Ammonites Tell Time* in the *Time of the Dinosaurs* Evidence Area.



The development of the Principles of Superposition and Faunal Succession allowed geologists to construct the Geologic Time Scale. A relative chronology, however, still doesn't tell you the actual age of a fossil or rock layer. Is it 30,000 years old or 2.5 billion years old? The development of radiometric dating allowed scientists to determine these kinds of "absolute" dates for fossils and rock layers.

3 HOW LIVING THINGS BECOME FOSSILS

Natural processes seem to favor recycling. Throughout the history of life on this planet, organisms have died, decomposed, and been reabsorbed by other living things. However, occasionally a plant or animal, or the traces they leave behind such as footprints, burrows, or root holes, will become a fossil. People are usually most familiar with fossils that are traces of living things that have been turned to stone—or **petrified**. However, not all fossils are stone. Most fossils retain original organic matter, such as **amber**—ancient tree sap that preserves insects. In *How Living Things Become Fossils*, you will find examples of the diversity of types of fossils and modes of preservation.

4 HOW THINGS TURN TO STONE— FOSSILS IN THE MAKING

Fossil formation depends on many factors: local environmental conditions, predators, the presence of water or oxygen, burial rate, mineral composition of surrounding materials, and the original material or **trace,** such as a track, burrow, or imprint. The relationship of these factors determines the type and quality of fossil that may later be found by paleontologists.

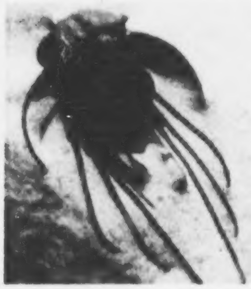
Fossil formation of the remains of a plant or animal requires conditions that are not favorable for decomposition. Ocean and lake floors and heavily sedimented riverbeds provide a suitable environment for fossil formation because of the fine silt, quick burial, and lack of exposure to oxygen. Sometimes volcanic eruptions, accidental burial in a cave, or other unusual situations will provide an environment capable of producing fossils. After burial, the original material undergoes many changes. Water may dissolve some of the original calcium carbonate or other minerals found in shells and bones. The cavities left behind and the porous spaces in bone and cell structures are subsequently filled with other minerals—silica, phosphate, pyrite, and so forth. This process is called **permineralization**. Fossils are found in various stages of permineralization and replacement, with original organic material still in place to varying degrees. In many instances, the entire organism may be dissolved, leaving a **mold** that is filled in with new material to create a **cast**. Fossil impressions, tracks, and burrows are usually preserved as cast-and-mold type fossils with the impression filled in with minerals. The famous leaf fossils of Florissant, Colorado, and the fossil fish from Kemmerer, Wyoming, are **compression** fossils, pressed like a flower in a plant press, leaving behind a carbon film that may ultimately be replaced with minerals. Fossils from these sites can be seen in the *Tropical Rockies* Evidence Area.

®Revised from *Museum Quarterly*,
1993 Summer Issue

A TRILOBITE *Finds a home in* PREHISTORIC JOURNEY

The *Prehistoric Journey* exhibition opened in 1995. Museum visitors are being treated to one of the world's most innovative and outstanding portrayals of ancient life. A large part of what makes *Prehistoric Journey* exceptional are the many extraordinary fossil specimens on display.

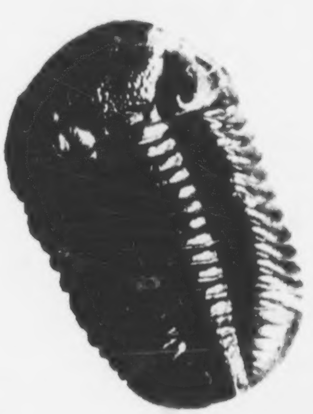
One specimen you will see when visiting *Prehistoric Journey* is a spectacular trilobite fossil. Called *Dicranurus hamatus,* it was discovered in the Harragan Formation in Oklahoma and is about 395 million years old. The specimen, roughly 4 inches long, was freed, grain by grain, from the rock matrix that surrounded it—a meticulous process that took more than 100 hours. The unusual spines on this specimen had one of two functions. They either worked like snowshoes, to keep the animal from sinking into the soft mud on the bottom of the sea, or served as protection against predators. When frightened, this trilobite rolled up into a defensive posture, appearing like a tiny armadillo with spikes. Enrolled, it looked bigger than life and unappealing as dinner. *Dicranurus hamatus* was chosen for *Prehistoric Journey* to show that many extinct animals, far from being primitive and poorly developed, were highly complex and beautifully adapted to their environment.



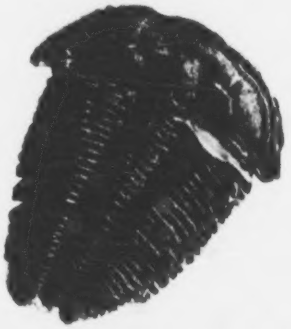
Dicranurus hamatus

Trilobites, named for their three distinct body segments, were an extremely diverse group of marine animals whose closest living relatives are crabs, lobsters, and shrimp. They appeared in the Cambrian Period (beginning 570 million years ago) and were the dominant mobile creatures in the sea, evolving even before fish. Many thousand species, ranging in size from a quarter of an inch to nearly 30 inches in length, have been discovered in marine sediments from around the world. Some were swimmers; others were slow-moving bottom dwellers. As a group, the trilobites became extinct at the end of the Permian Period, about 245 million years ago. A broad range of trilobites is displayed in *Prehistoric Journey* as an example of an entire group of amazing animals that no longer exists.

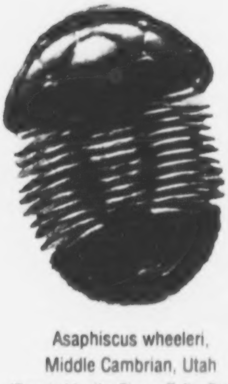
Kirk R. Johnson, Ph.D., Curator of Paleontology



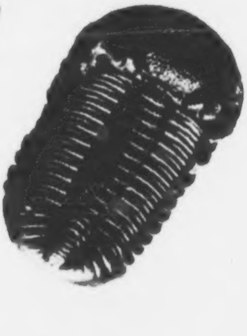
Phacops rana milleri,
Devonian, Ohio
Donated by Ruth Johnson



Alokistocare harrisi,
Middle Cambrian, Utah
Donated by the Steven Tuftin Estate

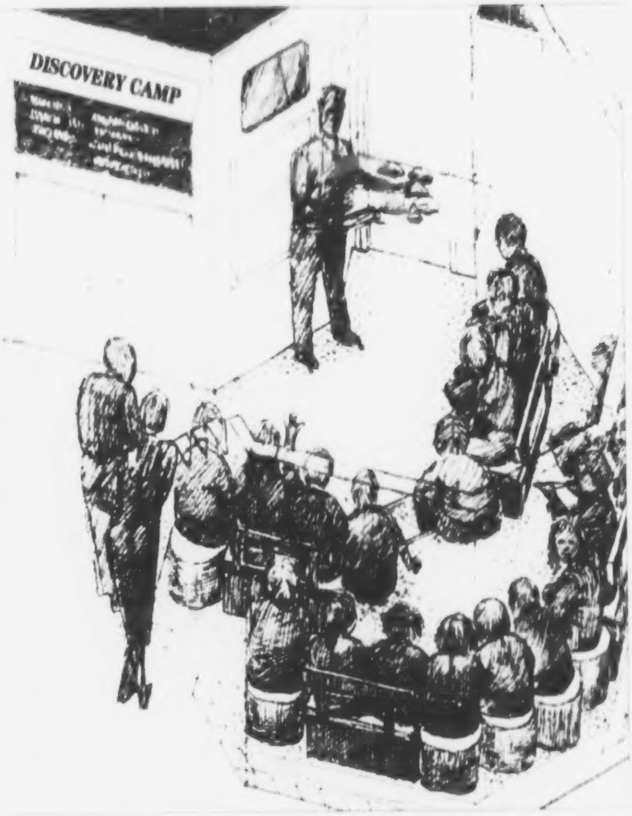


Asaphiscus wheeleri,
Middle Cambrian, Utah
(Donated by the Steven Tuftin Estate)



THE WORLD OF THE TRILOBITE

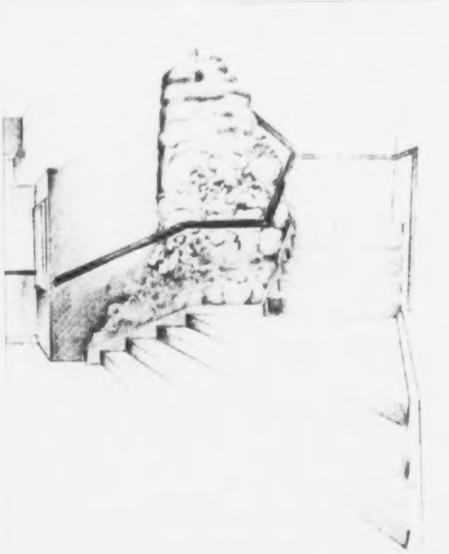
Look closely at the subtle differences among these trilobites.
Each specimen represents a different species.
All fossils are shown approximately life-size.



TRAILSIDE DISCOVERY CAMP

In the Discovery Camp, visitors experience hands-on interaction with fossil specimens, view demonstrations and educational video presentations, and work with Museum volunteers. This area may not be available at certain times during school hours due to use by guided tour groups.

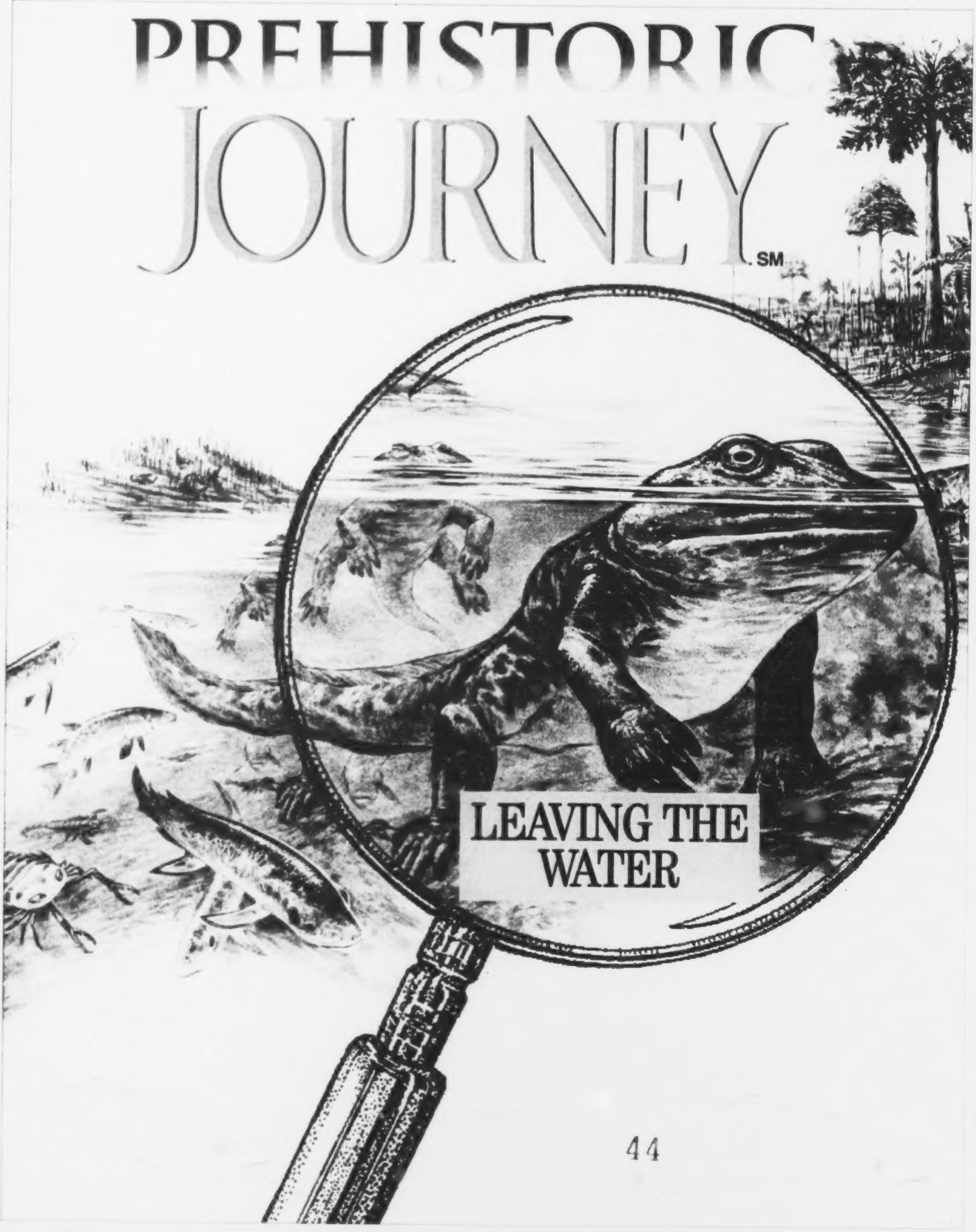
Artist rendition of the Discovery Camp area and staircase



LEAVING THE WATER STAIRCASE

The mural along the **staircase** allows students to imagine that they are the very first organisms emerging from the sea onto land. Living things that went from the sea onto land had three challenges—challenge your students: Don't dry out! Keep breathing! Don't collapse!

An **elevator** is located behind the stairs for individuals who cannot use the staircase. This elevator, along with another one positioned on the other side of the mezzanine, above the Cretaceous Creekbed, ensures that all visitors can experience the complete *Prehistoric Journey*.

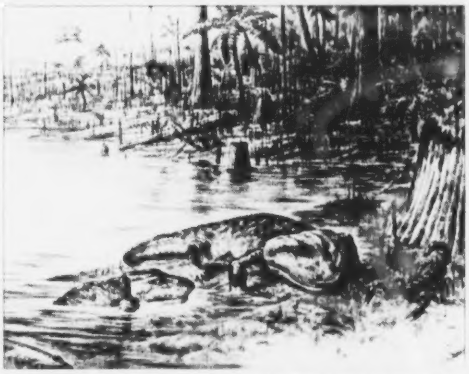

PREHISTORIC
JOURNEY SM
LEAVING THE WATER

Around the World in 4.6 Billion Years:

A VIRTUAL *PREHISTORIC JOURNEY*

EPISODE III:

Amphibious Landing on the Beaches of Wyoming



Please put your glove and helmet back on so the program can resume. Your trip through time left you in Wisconsin 395 million years ago. You were in the clutches of a giant claw and I am dying to see how things turn out.

Not so fast. What exactly was that six-foot-long "you-rip-ter-id" thing and how am I going to stand a chance against its claws?

That was a giant eurypterid, or sea scorpion. When I return you to Wyoming, 395 million years ago—30 million years from your last visit—I suggest you simply walk up onshore and leave it behind in the water.

Yeah, right, there's probably a bunch of dinosaurs on the beach waiting to attack me.

That would be most exciting; however, dinosaurs won't be around for another 180 million years. The only animals on land now are early relatives of your eurypterid nemesis. Surely you are not afraid of a few little scorpions.

Are you kidding? After that giant eurypterid, running into a scorpion would be like running from a velociraptor into the arms of Barney.

All right then. Program now running.

A leisurely stroll on the beach is one of the best ideas you've had yet. Hey, this isn't that simple. I feel like I weigh a ton—I'm drying up like a prune—and I can . . . hardly . . . breathe!

Sorry, ever-so-slight oversight on my part. I forgot to adjust your life support system for land. I'll readjust to keep you from collapsing and drying out, and to allow you to breathe air.

Boy, that reminded me of how heavy I feel when I pull myself up out of the swimming pool. How did animals without backbones make it out of the water?

Arthropods—scorpions, for instance—were some of the earliest animals on land. They already had an outer shell, or exoskeleton, to support their small, light bodies and keep in moisture, and they developed holes in their shells to allow them to breathe air.

Scorpions are okay, but compared to the water, things on land are pretty boring.

Boring? Look again.

Why? Well, there are those dinky little green things along the side of the water.

Those "dinky little green things," as you call them, are plants. Can't you recognize a plant when you see one?

I guess not, if you call something without any roots, seeds, or flowers a plant! But who cares about a bunch of plants anyway?

I'd care if I were you. Plants play an important part in producing the food you eat and the oxygen you breathe. If there were no plants, I venture to say there would be no you.

All right. I guess plants are pretty important. But what makes these particular plants so interesting?

Plants, like the ones here, were the first living things on land besides bacteria.

They *didn't have to worry about breathing and drying out. Right?*

They had to overcome the *same* challenges to living on land as animals did. Plants developed a waxy covering to prevent water loss, a system for structural support, and special holes in their waxy covering to allow them to take in carbon dioxide and give off oxygen. . . . You will now begin moving ahead through time again.

Wow! Plants are really going to town, but they still look strange to me.

You are witnessing the development of the first trees and forests.

Cool enough. Some of these trees are huge. But I'm still waiting for . . .

We are approaching 370 million years ago.

What's that big fish with legs?

That's an *Ichthyostega.*

Sounds like an icky Stegosaurus!

I told you, no dinosaurs yet.

I can't help it. I just can't wait for the dino part. I can't wait to see a T. rex *sink its teeth into one of those big, crested, duck-billed din—*

Hold your hadrosaurs, buster. If you don't experience the world before the dinosaurs, the world of the dinosaurs will not be as meaningful.

Says you. But you are controlling my life support system, so heeeey . . . back to that good old Ichthyostega!

Thank you. *Ichthyostega* was an early, primitive amphibian that lived mostly in the water. It still had a tail like a fish, but it also had four limbs. Amphibians, like frogs and salamanders, evolved from fish. Even today, some fish have both lungs and gills, and can breathe air for short periods of time. Others, like the walking catfish and mudskippers, can use their fins to walk!

Wow; I didn't know that. Now the next time I go fishing I can brag about "the one that walked away!" This is really fun. What's next?

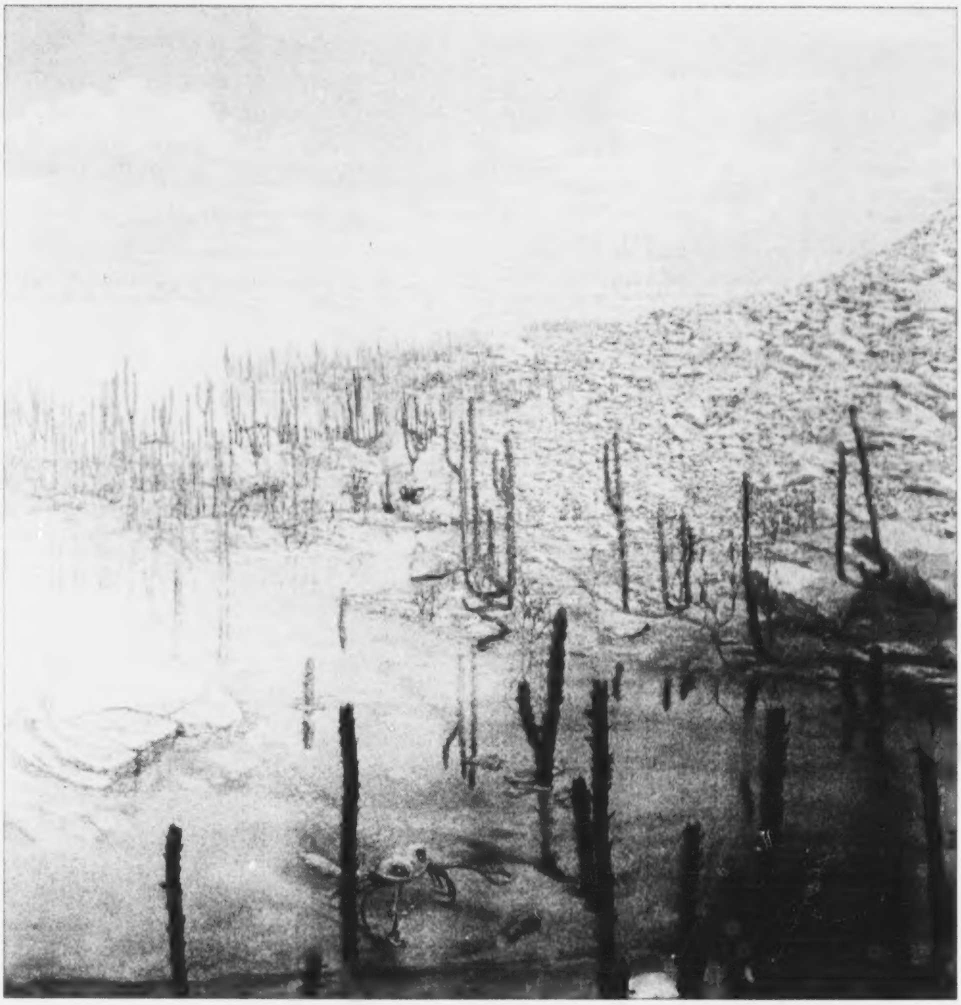
Are you familiar with the term "arachnophobia?"

EPISODE IV: If I Only Had a Wing

Rebecca Smith, Earth Sciences Educator

®Reprinted from *Museum Quarterly*, 1994 Winter Issue

BETWEEN TWO WORLDS DIORAMA



LEAVING THE WATER

Between Two Worlds

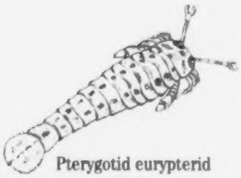
395 million years ago

THE LANDSCAPE SEEMS EMPTY, BUT LOOK AGAIN. PRIMITIVE plants lace the water's edge, gradually moving onto land. Arthropods, such as scorpions, are the first animal colonists, following plants onto a new world.

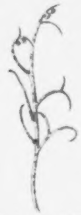
It has been 30 million years since the underwater world of the Sea Lily Reef.

LIFE MOVES ONTO LAND

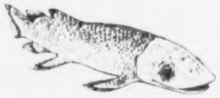
Beartooth and Bighorn Mountains,
Wyoming
Early Devonian Period,
395 million years ago



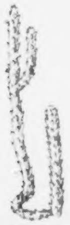
Pterygotid eurypterid



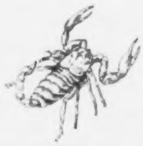
early land plant
Gosslingia americana



lungfish
Uranolophus wyomingensis



rooted plant with leaves
Drepanophycus devonicus



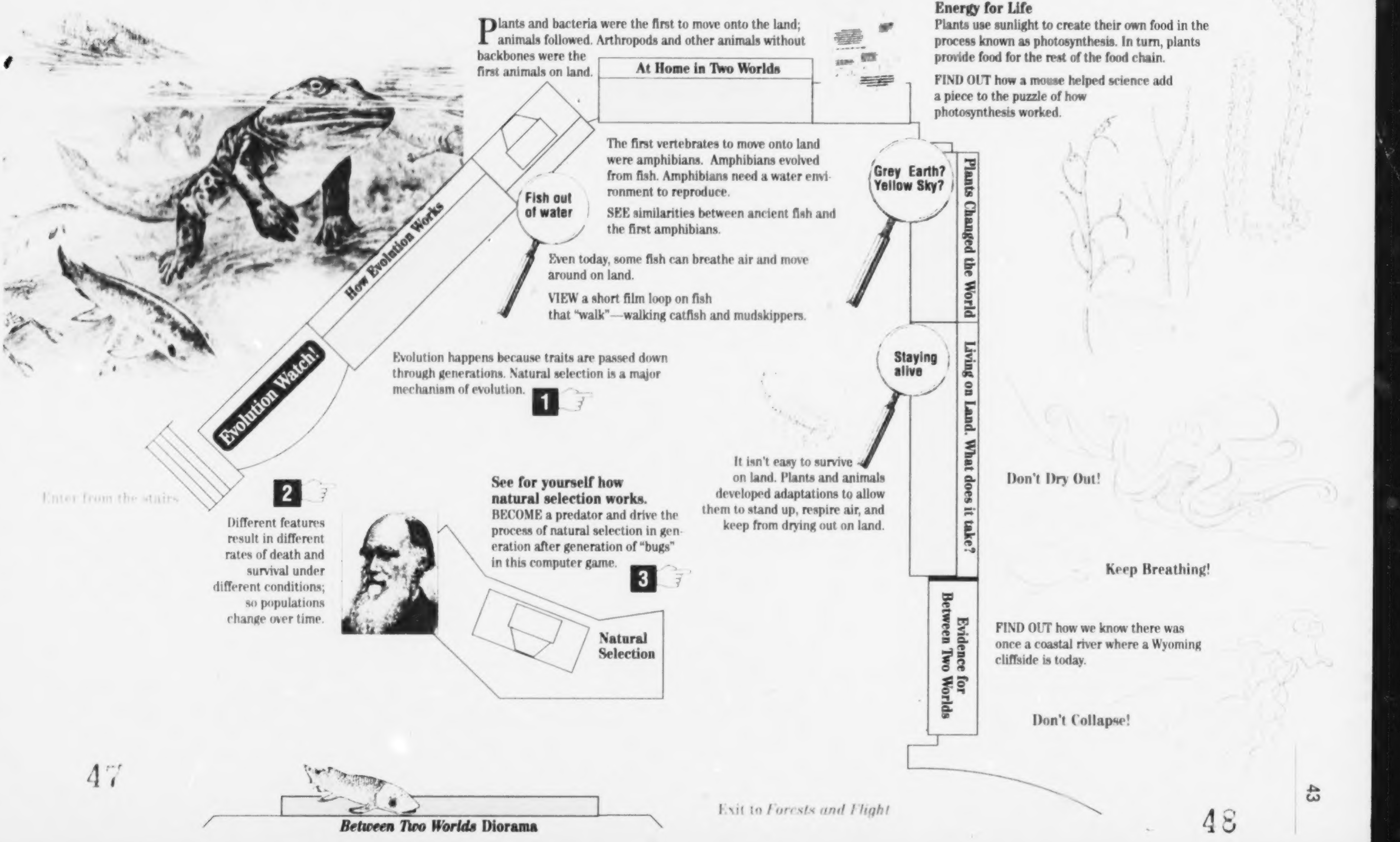
scorpion
Branchioscorpio richardsoni

small rootless plant
Psilophyton Wyomingensis

3. *Leaving the Water* Evidence Area Map

The land was empty until plants, and then animals, emerged from the sea.

Living on land required new adaptations in both plants and animals. Evolution is change over time, and all living things evolve.


At Home in Two Worlds
Fish out of water
How Evolution Works
Evolution Watch!
Grey Earth? Yellow Sky?
Plants Changed the World
Staying alive
Living on Land. What does it take?
Evidence for Between Two Worlds
Natural Selection
Between Two Worlds Diorama
Enter from the stairs
Exit to Forests and Flight
1
2
3
Don't Dry Out!
Keep Breathing!
Don't Collapse!

Plants and bacteria were the first to move onto the land; animals followed. Arthropods and other animals without backbones were the first animals on land.

Energy for Life

Plants use sunlight to create their own food in the process known as photosynthesis. In turn, plants provide food for the rest of the food chain.

FIND OUT how a mouse helped science add a piece to the puzzle of how photosynthesis worked.

The first vertebrates to move onto land were amphibians. Amphibians evolved from fish. Amphibians need a water environment to reproduce.

SEE similarities between ancient fish and the first amphibians.

Even today, some fish can breathe air and move around on land.

VIEW a short film loop on fish that "walk"—walking catfish and mudskippers.

Evolution happens because traits are passed down through generations. Natural selection is a major mechanism of evolution.

Different features result in different rates of death and survival under different conditions; so populations change over time.

See for yourself how natural selection works.
BECOME a predator and drive the process of natural selection in generation after generation of "bugs" in this computer game.

It isn't easy to survive on land. Plants and animals developed adaptations to allow them to stand up, respire air, and keep from drying out on land.

FIND OUT how we know there was once a coastal river where a Wyoming cliffside is today.

LEAVING THE WATER

Additional Background Information

WHY STUDY EVOLUTION?

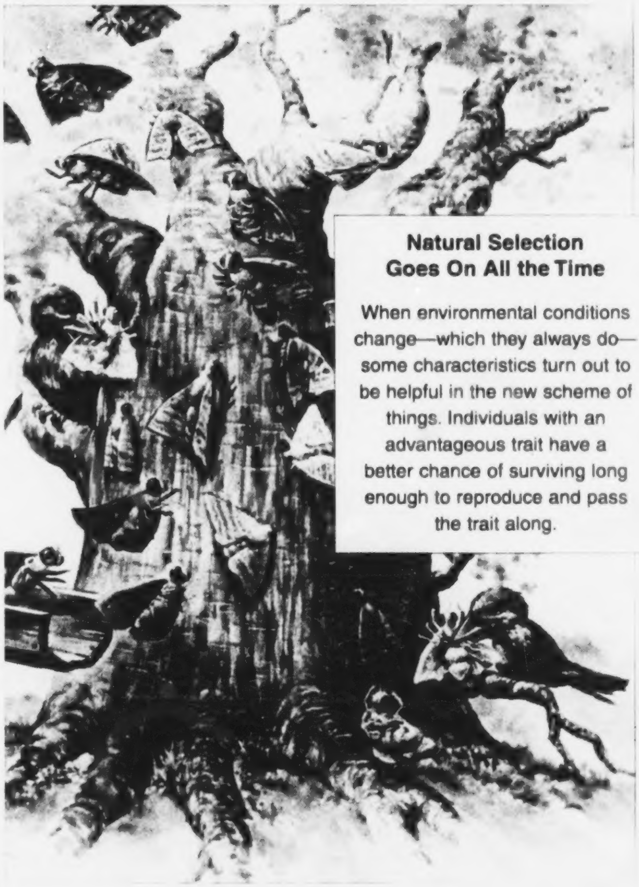
Modern sciences that study life and its history are built upon the central, unifying foundation of **evolution**—change through time. Understanding evolution is crucial to dealing with threats to human health and the environment. Today, evolutionary biologists are conducting research into such critical issues as understanding the AIDS virus and the nature of cancer, evaluating changes in biodiversity, and applying what we know about past changes in climate to understanding how humans are changing the Earth's atmosphere today. Although teaching evolution can create controversy, it is imperative that teachers not shrink from addressing one of the most important concepts in modern science.

Science begins with observations of the natural world—evidence. The evidence for evolution should be the primary subject covered when teaching about evolution. *Prehistoric Journey* and its related programs offer teachers a rich resource for teaching evolution. In *Prehistoric Journey,* students can see and touch the evidence of evolution—spectacular fossils of diverse organisms and their change through time. The exhibit can also provide students with a chronological and conceptual framework within which they can place subsequent information learned about life's history.

There are many references available on the controversy surrounding evolution, and a good resource library on the topic is important for teachers dealing with this subject. A particularly useful reference is *25 Creationists' Arguments and 25 Evolutionists' Answers: A Primer for Science Educators on the Evolution-Creationism Debate* by Michael Shermer, a publication of *Skeptic Magazine*. This publication, created for use in the classroom, can be photocopied for student use without further permission from the publisher. To obtain a copy, write to Skeptics Society, 2761 North Marengo Avenue, Altadena, CA 91001; Phone/Fax: (818) 794-3119. The bibliography on pages 166–170 of this Sourcebook contains additional references on evolution.

1 HOW EVOLUTION WORKS

Evolution is change in the characteristics of a population of organisms over a series of generations. The fossil record shows that species have changed through time, new species have appeared through time, and species have become extinct. When Charles Darwin put forth his theory of evolution, he did more than simply say that plant and animal species change over time. He also suggested a mechanism by which this change occurred. He called this mechanism **natural selection**. Natural selection is differential reproductive success—the fact that different rates of reproduction among organisms in a population result in shifts in frequencies of features over time. Different features can affect reproductive success depending on environmental conditions, so features that increase reproductive success tend to increase in a population. We now know that evolutionary changes depend on changes in the **genes** of individuals within a population. Deoxyribonucleic acid (**DNA**) is the molecule in organisms that transfers genetic information from one generation to the next.



Natural Selection Goes On All the Time

When environmental conditions change—which they always do—some characteristics turn out to be helpful in the new scheme of things. Individuals with an advantageous trait have a better chance of surviving long enough to reproduce and pass the trait along.

CHANGE HAPPENS WHEN GENETIC TRAITS are passed on, in different combinations each time, from generation to generation to generation.

In the last 100 years, the population of peppered moths in England went from being mostly light to mostly dark, because pollution darkened the bark of their favorite trees. There are many examples of evolution in action, but this one is often referred to because it has been so well documented.

LEAVING THE WATER

Additional Background Information

2 NATURAL SELECTION

Natural selection does not cause individual plants or animals to change during their lifetime, contrary to a common misconception. Natural selection is a process that causes large groups of plants or animals to change over the course of many generations. Another popular misconception is that natural selection is a force that tries to make species turn out a certain way, for example, by giving giraffes long necks so they could better eat leaves from tall trees. Nothing could be further from the truth! A more accurate way to look at natural selection is that for an accidental reason, some giraffes were born with slightly longer necks. (Of course, that far back, they wouldn't have been called "giraffes" yet.) Maybe their necks were longer because of some type of **mutation** in their genes or, maybe, some giraffes simply had longer necks, just as some people are taller than others. At any rate, these longer-necked giraffes had an advantage over the other giraffes—they were able to reach food that the shorter giraffes could not. More of the longer-necked giraffes survived to reproductive age and produced offspring.

Mutations introduce new characteristics

If neck length was not something that parent giraffes could pass on to their offspring, the story would end right here. The offspring of these giraffes would not necessarily have longer necks than other giraffes. But, if longer necks are passed down through the genes, you would expect there to be more giraffes with long necks in the next generation than in the last. Of course, not every offspring of a long-necked giraffe would have a long neck, and not every short-necked giraffe would fail to have offspring. However, after many generations, so long as the environmental conditions remained the same and the best food remained high up in the trees, there would be a shift in the population toward more long-necked giraffes.

Characteristics are inherited

SEXUAL REPRODUCTION

All of the above processes work only because natural variations exist in the individuals in a group. If every individual were absolutely identical to every other, natural selection and the formation of new species could never occur.

Where do these variations come from? Besides the introduction of new variations through mutation, the most important mechanism for producing variations in populations is the process of **sexual recombination** of genes. To see why this is, let's first look at an animal that does not reproduce sexually: the amoeba.

Amoebas reproduce by splitting apart. Each new amoeba has exactly the same traits as the parent. If the amoeba splits hundreds of times, every new amoeba is exactly the same. The only mechanism that can introduce genetic change is a mutation, or random alteration in the genetic code.

There is variety in any group

Compare the amoeba with animals and plants that reproduce sexually. Sexual reproduction takes two parents to produce new offspring, and the offspring have a mixture of genetic information from both parents. In fact, with the exception of identical twins, it is virtually impossible for any two individuals to be exactly the same. Think of how different siblings can often be.

Sexual reproduction is an extremely effective way of "mixing up" genes, producing new combinations of traits, and providing the "raw material" for natural selection.

Sexual recombination

LEAVING THE WATER

Additional Evidence Area Concept Information

GENETIC DRIFT

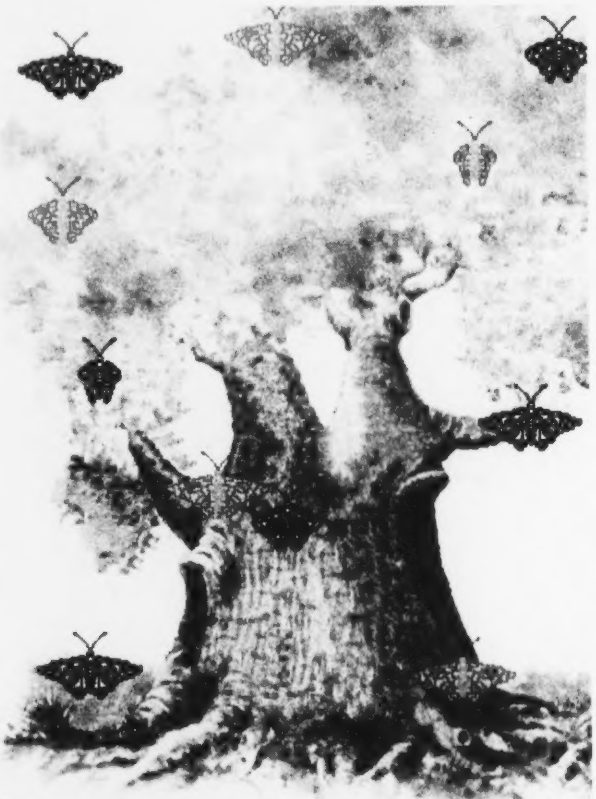
Natural selection is one of the principal ways that certain traits in a group become more prevalent over the course of many generations, but it is not the only way. Sometimes the laws of chance alone can account for certain traits evolving.

By way of example, imagine that you were to flip 100 pennies. Chances are high that you would have about 50 heads and 50 tails. It would be no surprise if you had 48 heads and 52 tails. However, on occasion, you might have 95 heads and only 5 tails. While that is not very likely, it certainly could happen. In fact, if you were flipping coins for a billion years, at some point or another it almost certainly would happen.

The same is true with the mixing of traits in sexual reproduction, which has been occurring for billions of years. Occasionally, by chance alone, a particular trait becomes widespread in the group, or another trait is eliminated. Once this happens, the new traits are passed on to the next generations and shape the evolution of the species. This process is called **genetic drift**. And just as getting all heads is more likely with 10 coins than with 1,000 coins, chance, in the form of genetic drift, influences the genetic makeup of small populations more than larger populations. Therefore, because genetic drift occurs, not all characteristics evolved because they were adaptive—they may have been neutral.

3 ☞ SEE FOR YOURSELF HOW NATURAL SELECTION WORKS

To make this process concrete, the Natural Selection Computer Game in the exhibit allows you and your students to experiment on a small group of fictional "bugs" to see how natural selection actually works. The bugs in the starting group come in two types: fast but easy-to-see bugs, and slow but camouflaged bugs. During the course of the game, you play the part of the predator, trying to catch as many bugs as possible in the allotted time. Only the bugs that survive are able to reproduce to form the next generation (*some genetic processes have been simplified to keep play time to a reasonable length*). As you watch this process unfold over many generations, you will be able to see how the population slowly changes. In fact, each time you play the game, the results may be different, depending on which bugs you are able to catch and how the survivors pair up to mate and reproduce. This game illustrates how natural selection works in the real world. After all, if every group of prehistoric single-celled animals evolved in the same way, we would have only one type of animal on Earth today!



TEACHER TIP

TEACHING EVOLUTION

How One Teacher Handles the Controversy

Let's face it, when it comes to hot-button issues in education, few rival evolution as a topic that quickly ignites deep-seated emotions. Defenses go up and swords are brandished, as positions are staked out along lines of religious and philosophical beliefs. So no wonder teachers avoid the "E" word, and look at me like I'm out of my mind when I tell them we have wonderfully engaging discussions about evolution in our classroom. Here's how I manage to do so with, to date, no serious casualties.

To begin with, regardless of my scientific background, I'm not out to change anyone's beliefs. When we discuss evolution I know there are children in my classroom who are raised with varying religious beliefs. I present evolution as a scientific interpretation of nature based on fossil evidence and what we know about living animals, including humans. We learn how natural selection causes changes in populations over time. There are recognizable forces of change that are observable and verifiable. We then look at how these forces can be used to explain how animals become extinct, or how living species might have originated.

Second, although I don't introduce the topic of religious beliefs, I don't shy away from discussing them either and letting students explain their own. After all, it's the human chapter in evolution that ruffles feathers, but the role of humans in the cosmos is also central to any religion. It can be unsettling for a child to have their family's beliefs challenged by someone in authority, especially by their teacher. Thus by allowing children to express their ideas and beliefs, I foster an atmosphere of acceptance of personal differences and mutual respect. When sparks fly, as they occasionally do, I encourage students to be aware of their emotions surrounding the issue. Tolerance for different religious beliefs, I remind them, is one of the core ideas in the founding and health of our society.

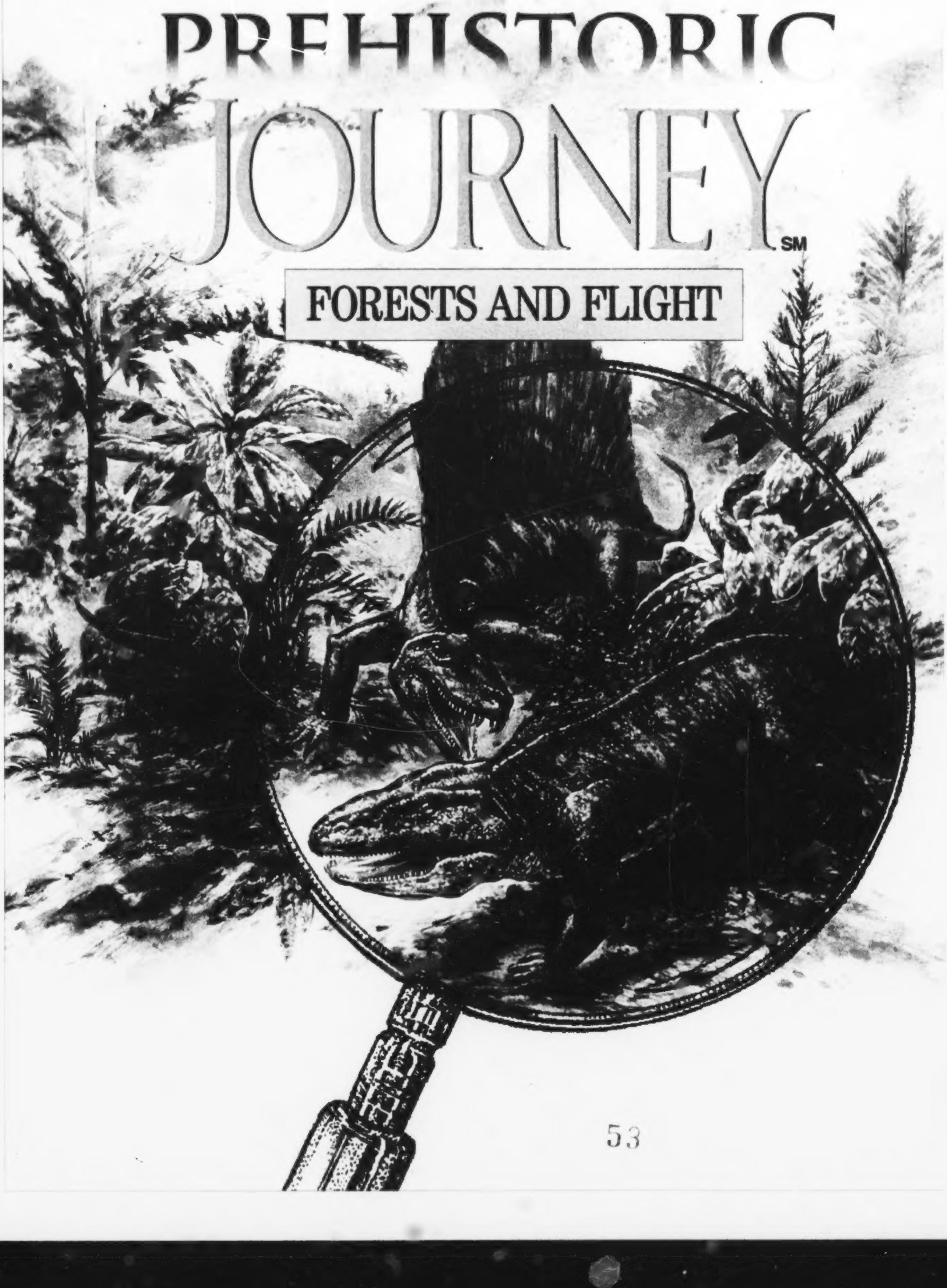
Third, I let parents know what I'm doing. I send a letter in advance of the unit explaining that how life changes over time, or evolution, will inevitably come up. I assure them that I present it as a widely accepted scientific interpretation of how nature works, but that I intend to respect each student's personal values. I encourage parents to contact me if they have concerns in this area, so that we can discuss the issue and come to a consensus on how to best meet their child's needs. The feedback I've received in doing this has been extremely positive. Parents appreciate my openness and respect for their values, and have been very accommodating.

Following these guidelines, I've been able to handle a number of issues, from Halloween to animal rights. My overall experience has shown that when parents are informed and listened to, when different beliefs are accepted and respected, then children can expand their awareness and tolerance for others.

Sincerely,

Thomas Adorney

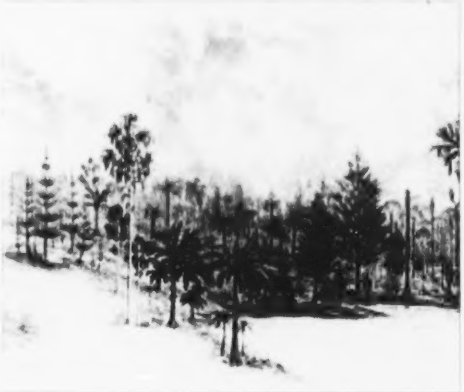
Fourth Grade Teacher
Kiffin Elementary School


PREHISTORIC
JOURNEY
SM
FORESTS AND FLIGHT

Around the World in 4.6 Billion Years:

A VIRTUAL *PREHISTORIC JOURNEY*

EPISODE IV:
If I Only Had a Wing



Now would be a good time to pause your virtual reality trip through time. You have traveled through 90 percent of Earth's history

And still no dinosaurs!

True, but a lot *has* happened. You have witnessed the origin of life, the ancient seas teeming with a rich diversity of living things, and the movement of early plants and animals onto land.

Don't forget fish evolving into amphibians, which means reptiles, really huge, meat-eating, dinosaur reptiles, can't be far behind!

Correct. 370 million years ago is where I paused the program, and the first reptiles are 340 million years old. They are, however, little, 4-inch-long lizardlike creatures with small, simple teeth, more suitable for eating bugs than brachiosaur meat.

How long until dinosaurs after that?

80 million years.

Good—let's hurry up and get started.

Helmet?

Check.

Glove?

Check. Full speed ahead!

Program running. Argentina. 305 million years ago.

It's sort of dark; why did the program start here?

I thought you might enjoy a glimpse of a *Megarachne servinel.*

A mega-what?

A very large spider that frequents these parts.

Oh, cool, like a tarantula?

Not quite. The bodies of megarachnids are more than a foot in length and they stand as tall as an average house ca . . .

Gulp! Uh, I don't know if it's such a good idea to look for one of those. Besides, I don't see anything around here except this soft, black kitty.

That is not a cat. Remember—there are no mammals yet. You have been petting a megarachnid spider.

Yeow!!!!

You have scared it away now, so you can calm down.

I can calm down, but I'm not sure if I can come *down. I think I'm flying!*

Well, indeed you are—a virtual prehistoric Peter Pan, I would say. I guess that spider gave you quite a scare; you have just flown a few thousand miles and a few million years.

I've been frightened before on this trip, but this is the first time I've been flightened.

That is because flight has only recently evolved in your journey through time, which means that you are now in what some affectionately call the Age of Insects. The air is now alive. Listen. Flapping and buzzing sounds abound.

The Age of Insects? I don't remember that from school. When did it end?

It has not ended yet. In 1995, 70 percent of all animals are insects. That is more than 300 million years of dragonflies, cockroaches, millipedes, and crickets. Watch out for those cliffs . . .

Thanks for warning me. It's hard to see those gray cliffs in the evening. . . . Wow! What a beautiful forest. It's so green, and even though the trees look pretty strange, those ones with needles look a little like conifers. I can hear the waves where that stream is leading out to sea. We must be somewhere on the west coast of the United States, like in Oregon or Washington.

Try Kansas. 295 million years ago.

Kansas, huh? No kidding. So who's the king around here?

The closest thing to a cowardly lion in *this* forest is that 2-foot-long edaphosaur.

That sail-backed reptile?

Protomammal to be precise. It is the closest thing to a mammal yet. Specialized tooth and jaw structures are some of the things that make it an evolutionary branch on the way from the common ancestor of reptiles and mammals to mammals.

Whoa. That dragonfly's huge. And look at that giant millipede. Wow. Arthropods have really arrived. But those big, round, 3-inch-long cockroaches are a little too much for me. Oh, that's right, I forgot I can fly.

You are now flying rapidly through time and space. If you look down, you will observe . . .

. . . that the continents are moving together. I know about this. It's the supercontinent called Pangaea. But, you know, it appears that living things are starting to get pretty sparse down there.

Your observation is correct. You are approaching 250 million years ago, and are witnessing the greatest extinction in the history of life. By 245 million years ago, as many as 96 percent of all species will disappear from the Earth.

I should do something. This is awful.

Extinction is a natural occurrence; it paves the way for new species.

Oh, like dinosaurs?

Exactly.

EPISODE V: Somewhere over the Oxbow

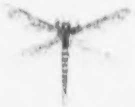
Rebecca Smith, Earth Sciences Educator

®Reprinted from *Museum Quarterly*, 1995 Spring Issue

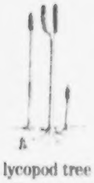
EARLY LAND ANIMALS

Hamilton, Kansas

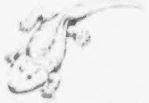
Late Pennsylvanian Period,
295 million years ago



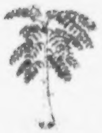
giant dragonfly
Meganeura sp.



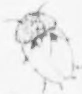
lycopod tree
Sigillaria brardii



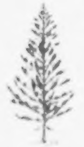
small amphibian
Amphibamus sp.



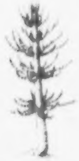
seed fern
Neuropteris sp.



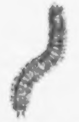
early cockroach
orthomylacrid cockroach



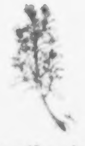
early conifer
Walchia piniformis



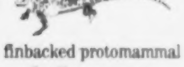
sphenopsid plant
Calamites sp.



giant millipede
euphoberiid millipede

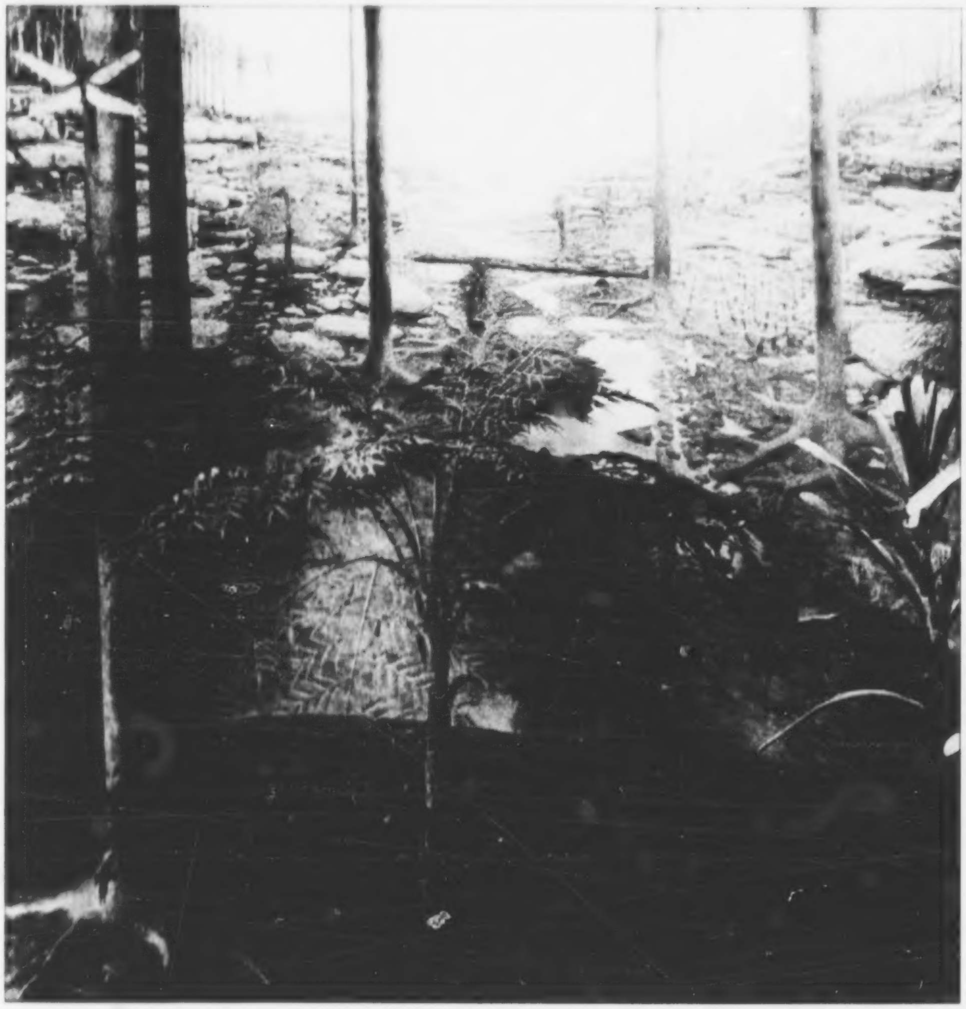


conifer relative
Cordaites principalis



finbacked protomammal
Ianthosaurus sp.

KANSAS COASTLINE DIORAMA



FORESTS AND FLIGHT

Kansas Coastline

295 million years ago

AMPHIBIANS AND FINBACKED REPTILES LIVE NEAR THIS coastal stream in one of the first forests. Large dragonflies fly among the primitive trees, while big cockroaches and millipedes crawl on the forest floor.

It has been 100 million years since life moved onto land in Between Two Worlds.

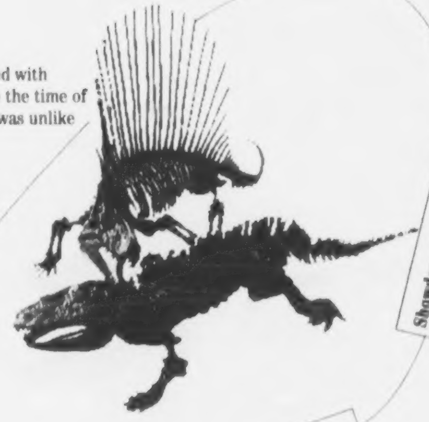
4. *FORESTS AND FLIGHT* EVIDENCE AREA MAP

Once life was established on land, there was no stopping it. Plants and animals got larger and better adapted to land. Forests developed, and some insects took to the air.

Enter from Leaving the Water

Kansas Coastline Diorama

The *Dimetrodon* is sometimes confused with dinosaurs. However, they lived before the time of dinosaurs and had a sprawling gait that was unlike the upright stance of dinosaurs.



Showdown in North Texas

OBSERVE a showdown in north Texas between the giant amphibian *Eryops* and protomammal *Dimetrodon.*

Ancient Plants Light Up Your Life! The heat from burning coal comes from energy stored millions of years ago by living plants. Most coal is formed from buried swamps.

300-million-year-old Pennsylvania Forest Floor

These leaf fossils are from a seed fern (pteridosperm). They look like ferns—but they aren't—true ferns reproduce by spores.

Creepy Crawlies

Some Paleozoic insects were huge.

Forests eventually covered the land. The trees of the first forests were very different from today's.

SEE the boomerang-headed amphibian *Diplocaulus,* a victim of the Permian Extinction.

Extinction is a natural process. Extinctions have occurred throughout the history of life.

Victims of the Permian Extinction

Extinction Episode

The Permian extinction was the greatest extinction in the history of life on Earth, much bigger than the dinosaur extinction. Many factors may have contributed to the extinction.

First Forests

Modern Greenhouse

By burning fossil fuels, we have changed the balance of the Earth's carbon cycle. Ancient plants contribute to today's greenhouse effect. **1** ☞

Creative Packaging

Eggs and Seeds

TOUCH a model of amphibian eggs. SQUEEZE a puffball to release its spores.

Eggs and seeds are similar, and evolved in similar ways.

Amphibians Become Reptiles

Reptiles evolved from amphibians. Reptiles are like amphibians in some ways, but very different in others. Because of eggs, reptiles are not tied to water for reproduction. TOUCH reptile skull sculptures.

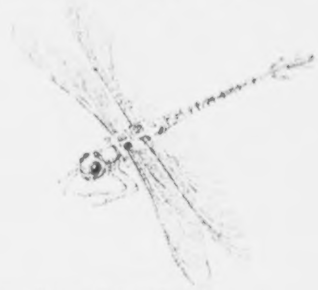
Insects Begin to Fly

Insects were the first animals to fly. **2** ☞

Evidence of a Kansas Coastline

FIND OUT how we know that there was once a coastal backwater where a Kansas cow pasture is today.

Exit to Mesozoic Time Station



How does a dragonfly fly?

The primitive flight mechanisms of dragonflies actually create more lift than modern high-performance aircraft.

WATCH how a dragonfly flies.

FORESTS AND FLIGHT

Additional Background Information

1 MODERN GREENHOUSE—THE GREENHOUSE EFFECT

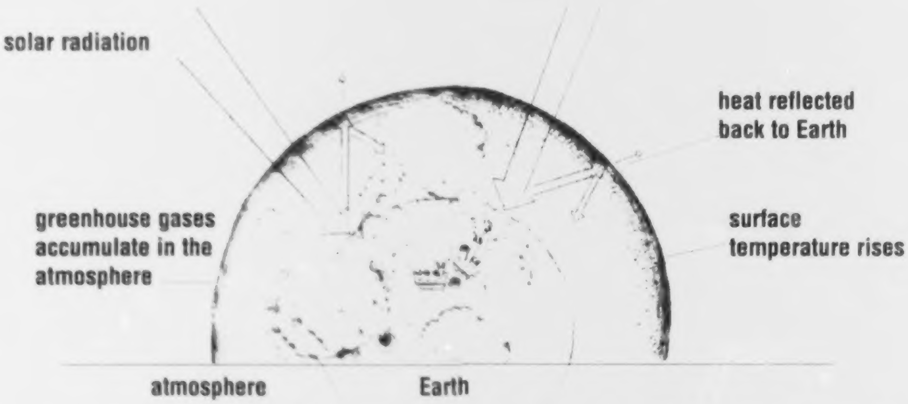
Did you know that the Earth's atmosphere is like a giant greenhouse? Greenhouses are buildings made especially to grow plants any time of year. Sunlight shines through the glass or plastic greenhouse walls and warms the air, soil, and plants. The walls keep much of the warmed air inside, making the greenhouse warmer than the outside air. This warm environment is ideal for many plants.

Earth's atmosphere—the layer of gases surrounding the planet—acts like a natural greenhouse. Sunlight passes through our atmosphere, is absorbed by the Earth, and is changed into a different form of energy that we sense as heat. This energy is naturally radiated away from the Earth into outer space, but some gases in the atmosphere keep much of the heat "inside." Without special gases like carbon dioxide in the atmosphere, our warm planet would be cold and lifeless.

This process, known as the **greenhouse effect**, is natural and has been going on for billions of years. Humans may be adding to the greenhouse effect because our activities over the past hundred years have increased the amount of heat-trapping gases in the atmosphere.

From ancient plants to a Modern Greenhouse

Plants photosynthesize carbon dioxide (CO_2) from the atmosphere into carbohydrates that they store in their stems and leaves. Over 50 billion tons of carbon are cycled through plants EACH YEAR!


solar radiation
heat reflected back to Earth
greenhouse gases accumulate in the atmosphere
surface temperature rises
atmosphere
Earth

When plants die, the carbohydrates in their bodies break down into hydrocarbon molecules. Under the right circumstances, those hydrocarbons turn into coal, peat, or other fossil fuels.

When we burn fossil fuels, the carbon that was stored long ago is released back into the atmosphere. Human use of fossil fuels has caused a significant increase in atmospheric CO_2. Projections show that CO_2 levels could double in the next century.

Atmospheric CO_2 traps solar energy, much like glass windows trap heat in a greenhouse. Twice the present amount of atmospheric CO_2 would eventually cause a two- to three-degree Celsius increase in average global temperature—enough to cause partial melting of polar ice caps, a rise in sea level, changes in local climates, and major precipitation changes.

The systems of our planet are complex. Earth's climate has changed in the past and will continue to change. We are beginning to realize that humans are affecting the climate. Studying the past helps us predict the future, and make better choices in the present.

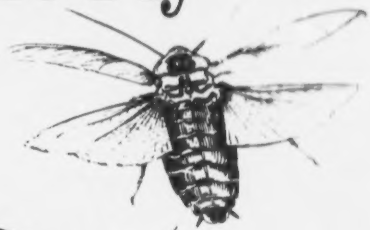
FORESTS AND FLIGHT

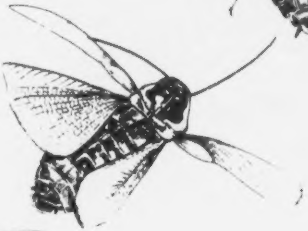
Additional Background Information

2 Insects Begin To Fly

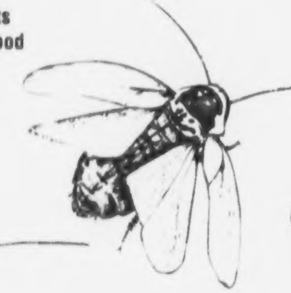
BY 300 MILLION YEARS AGO, the skies were no longer empty.

Insects, including dragonflies and cockroaches, had taken to the air.

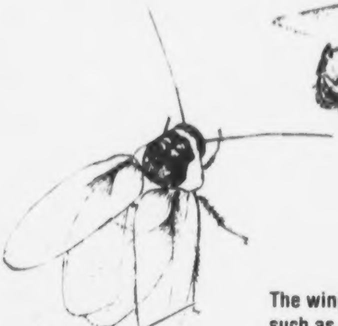


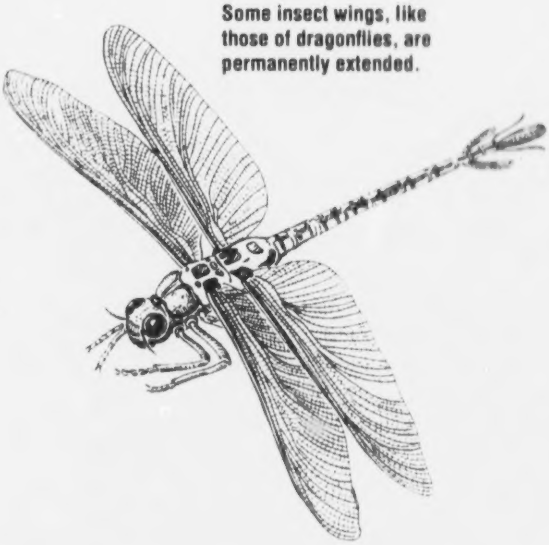


Self-propelled flight was a great innovation. Insects used their wings to find food and escape predators.

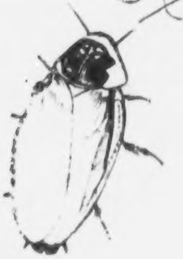


Some insect wings, like those of dragonflies, are permanently extended.

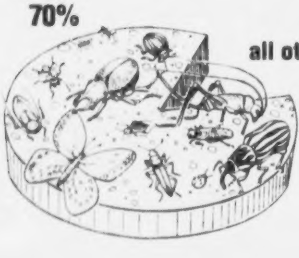




The wings of some insects, such as cockroaches, fold up.



Paleozoic dragonflies came in a range of sizes. Many were bigger than modern dragonflies. Some were the size of seagulls!



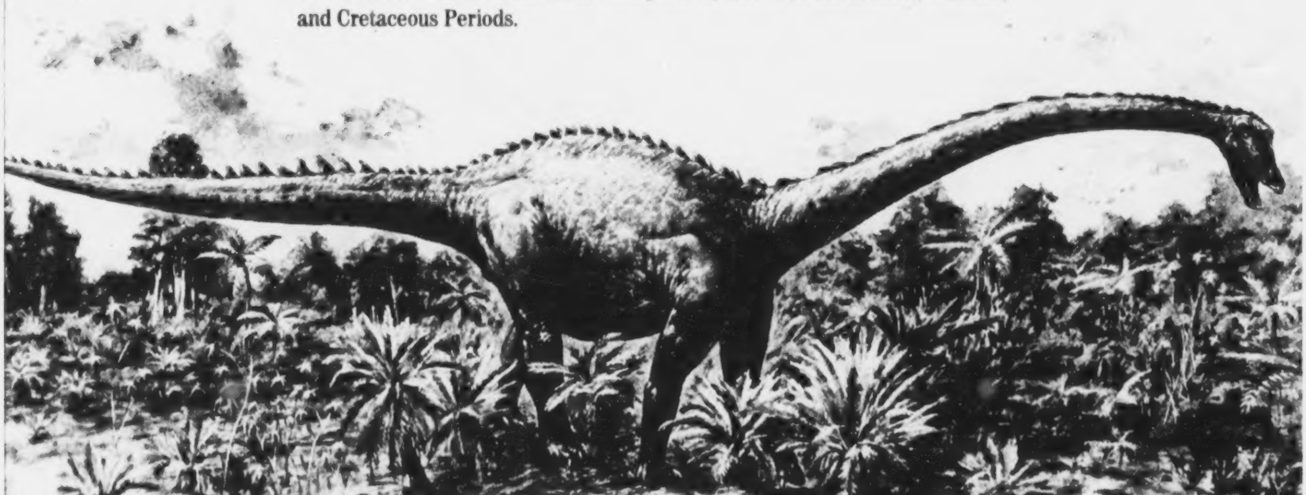
Arthropods were the first animals on land—and they were the first animals to develop wings and fly. Not surprisingly, insects are still the most successful group of animals on Earth. More than 70 percent of the species alive today are insects.

MESOZOIC ERA

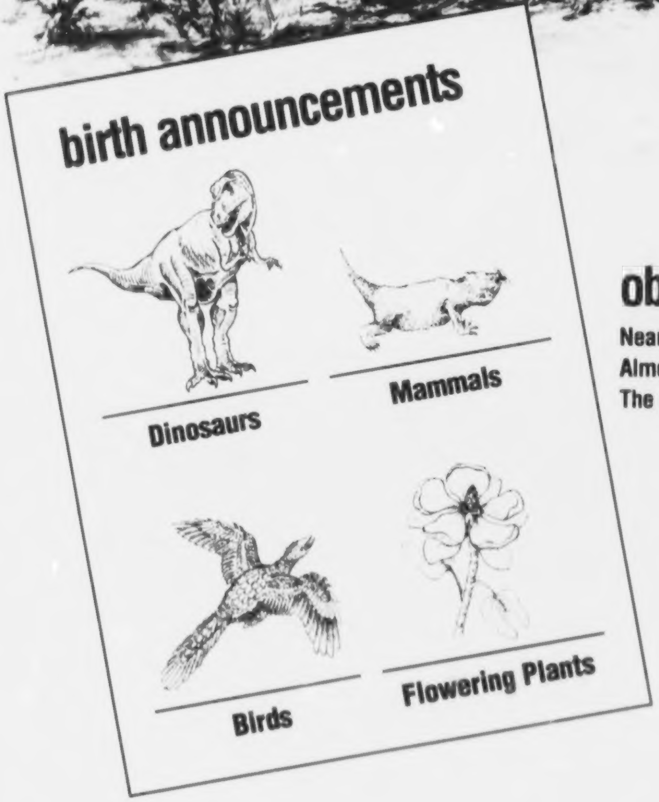
251 – 65 MILLION YEARS AGO

The **Mesozoic era** lasted almost 200 million years. The deaths of nearly all Paleozoic species of animals and plants paved the way for the span of time known as the Mesozoic Era.

The Mesozoic Era includes three time periods, known as the Triassic, Jurassic, and Cretaceous Periods.



birth announcements



obituaries

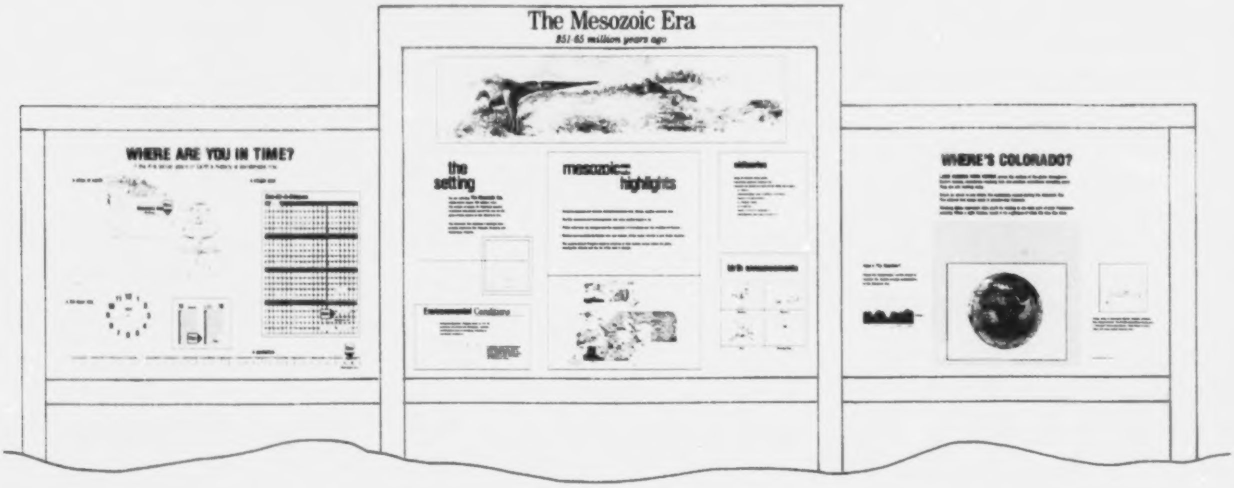
Nearly all Paleozoic marine species

Almost three-quarters of species on land

The plants and animals you saw in the last exhibit area are gone:

- All trilobites
- Most brachiopods, corals, bryozoans, and crinoids
- Nearly all the big amphibians
- All finbacked reptiles
- All eurypterids
- Nearly a third of the insect orders
- Most cordaites, scale trees, and seed ferns

MESOZOIC TIME STATION


The Mesozoic Era
251-65 million years ago
WHERE ARE YOU IN TIME?
the setting
mesozoic highlights
Environmental Conditions
WHERE'S COLORADO?

MESOZOIC ERA HIGHLIGHTS

Dinosaurs appeared and were the dominant animals on land. Marine reptiles ruled the seas.

The first mammals and birds appeared, and some reptiles began to fly.

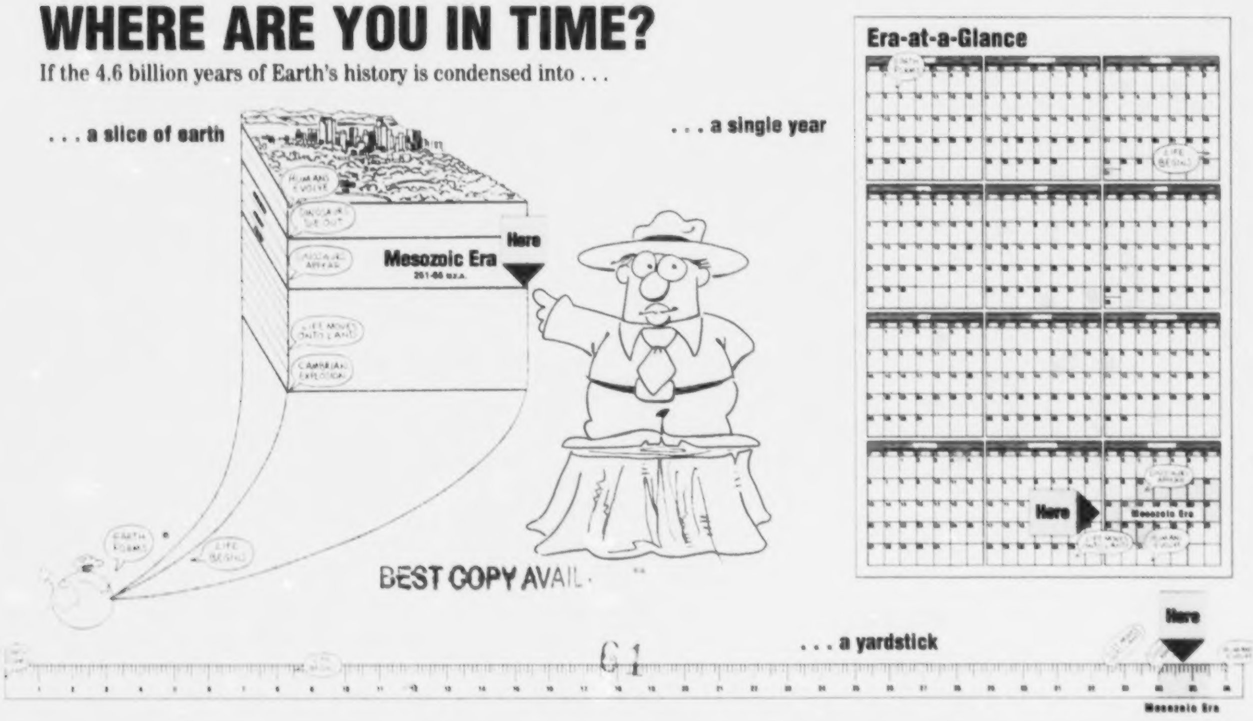
Plants underwent big changes with the expansion of seed plants and the evolution of flowers.

Shallow seas periodically flooded onto and drained off the center of what is now North America.

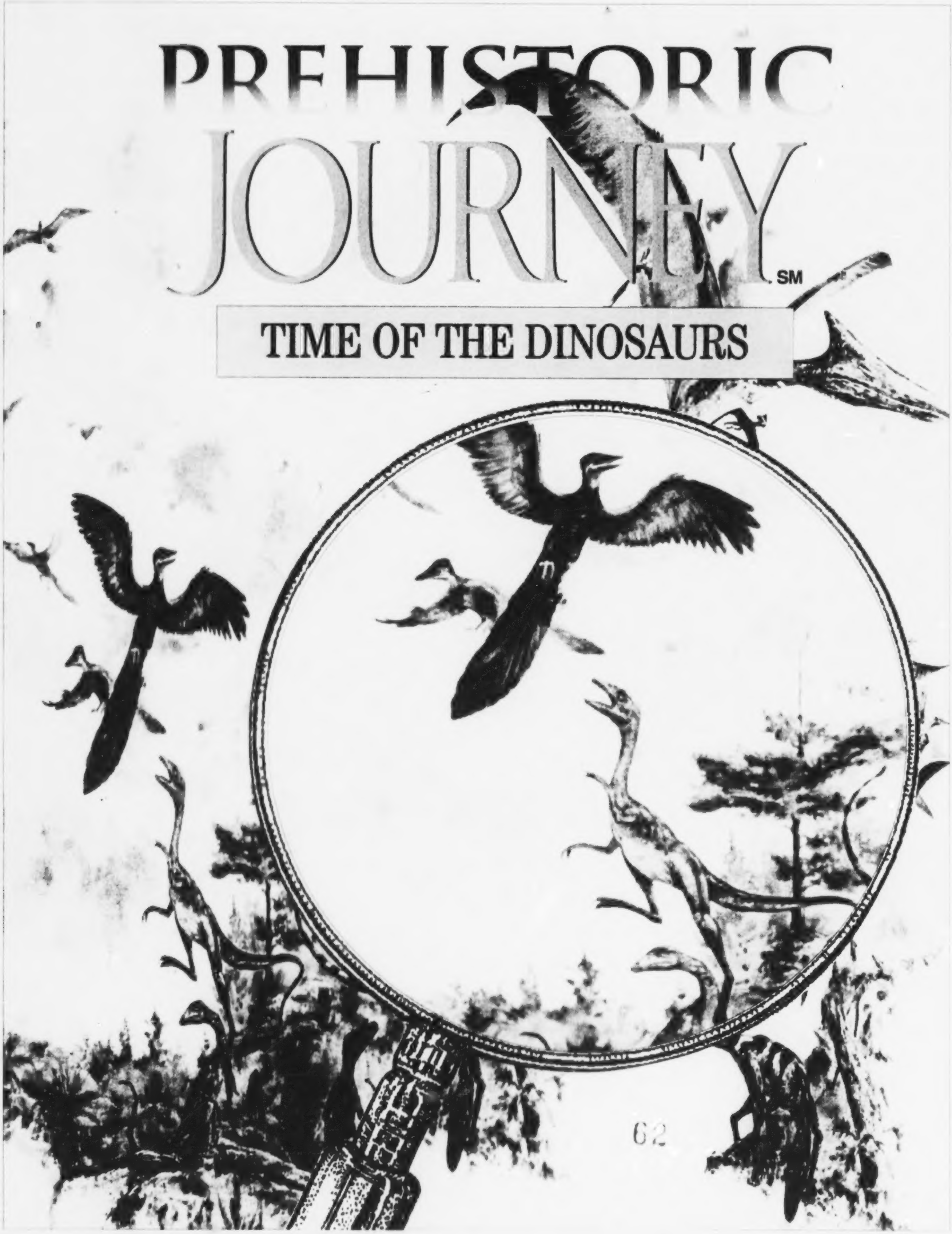
The supercontinent Pangaea began to break up as land masses moved across the globe, causing the climate and the lay of the land to change.

WHERE ARE YOU IN TIME?

If the 4.6 billion years of Earth's history is condensed into . . .


. . . a slice of earth
HUMANS EVOLVE
DINOSAURS DIE OUT
DINOSAURS APPEAR
Mesozoic Era
251-65 m.y.a.
Here
LIFE MOVES ONTO LAND
CAMBRIAN EXPLOSION
EARTH FORMS
LIFE BEGINS
. . . a single year
Era-at-a-Glance
Here
Mesozoic Era
. . . a yardstick
Here
Mesozoic Era

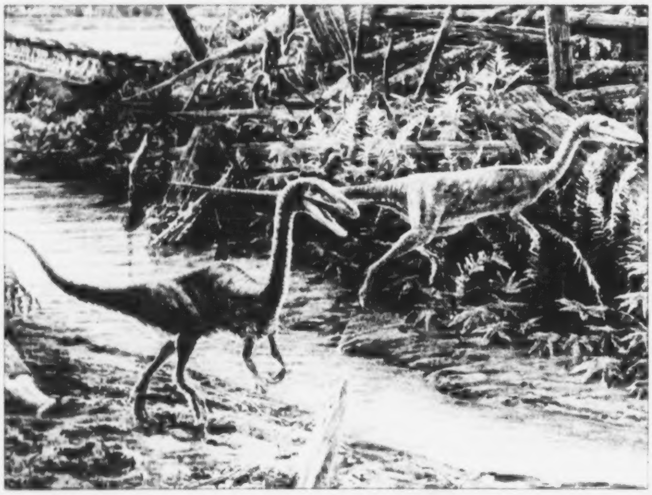
BEST COPY AVAIL


PREHISTORIC
JOURNEY SM
TIME OF THE DINOSAURS

Around the World in 4.6 Billion Years:

A VIRTUAL *PREHISTORIC JOURNEY*

EPISODE V:
Somewhere over the Oxbow



Something gives me the feeling we're not in Kansas anymore. The coastline is gone. This place is covered with rivers and streams.

Correct. We have flown millions of years ahead in our virtual reality program into what is known as the Triassic Period. We are currently near the equator, in what will be New Mexico 220 million years from now.

Well, I have always been fond of New Mexico, but you don't have to shout about it!

Shout? I am not shou . . . Oh. I need to adjust your audio for mammalian hearing.

What are you talking about—I've had mammalian hearing since I was born.

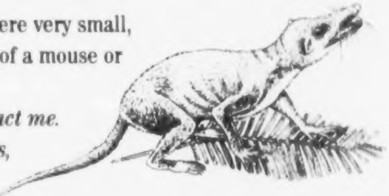
Perhaps, but not during the run of this program. Mammals have just evolved, and the program is allowing you to experience the world as an early mammal. Mammals are distinguished from reptiles by the structure of their jawbone and inner ear. Bones that once resided in the jaw of the common ancestor of reptiles and mammals have evolved into bones of the inner ear in mammals, giving them more sensitive hearing.

Mammals . . . hey, wait a minute. Don't tell me we flew right past the Age of Reptiles and into the Age of Mammals. You promised me dinosaurs!!!

Now *you* are shouting—of course, it is more like squeaking at your present size.

My size?

Early mammals were very small, about the size of a mouse or a shrew . . .



Don't try to distract me. I get dinosaurs, or I stop the program!

No need to do that. Mammals originated at the same time as dinosaurs. We are currently in the first part of the Age of Dinosaurs. As a matter of fact, here come some early dinosaurs now.

Where? All I can see is a bunch of big turkey feet running by.

Those are not turkey feet, they are dinosaur feet. *Coelophysis* dinosaur feet, to be precise.

Seal-o- . . . ?

Coelophysis. Coelophysis was a swift, agile, predatory dinosaur. Full-grown ones were 8 feet long, and with their long, slender hind limbs, long neck, and large eyes, they were very birdlike. Beware, I believe one of them has noticed you.

Noticed me? Uh oh! That thing has sharp teeth . . . and claws. I'm getting out of here!

Well done. Hiding in that hole was an excellent idea. That is exactly what your ancestors would have done.

As long as I'm safely hidden, could you bring out some more dinosaurs?

Okay then, I will run the program forward into the Jurassic Period, around 153 million years ago.

Excellent. We're talking Triceratopses, T. rexes, *and* Velociraptors *now!*

Actually, those particular dinosaurs did *not* live during the Jurassic Period. They come from the time period after the Jurassic.

Well, at this point, just about any bunch of big, red-blooded, bloodthirsty, American dinosaurs will do . . . Hey. That's more like it. It's big, ferocious, has sharp teeth, and three claws—has to be an Allosaurus. *And that one with the plates down its back and spikes on its tail must be* Stegosaurus. *Now we're talking dinosaurs. And the* Allosaurus *is trying to bite the* Stegosaurus *in the throat—it's dead dinosaur meat for sure.*

Not necessarily. That stegosaur's throat is covered by a bony armor.

Is that a recent discovery?

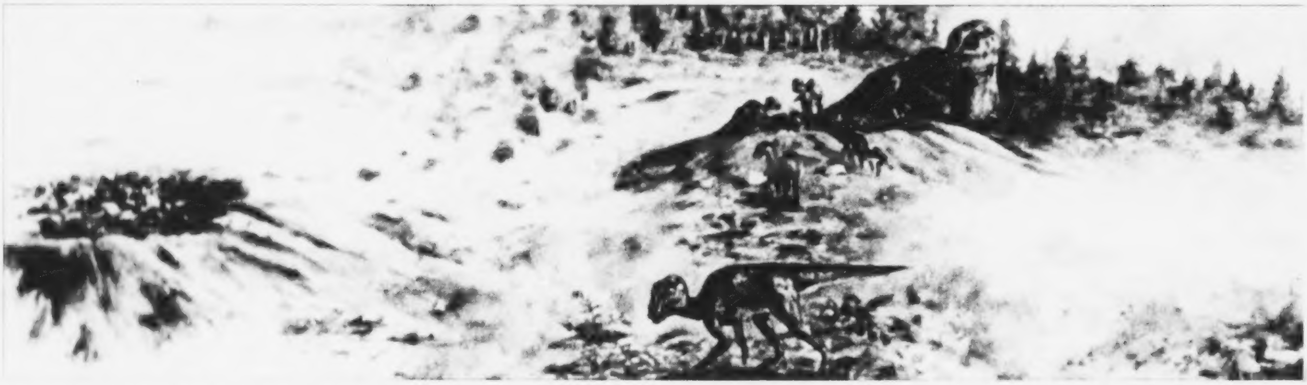
Do you read the papers?

Well, maybe I saw something about . . . oh, yeah. The Denver Museum of Natural History found a new Stegosaurus *skeleton near Cañon City, Colorado, in the summer of 1992, and the skeleton had bony armor around the throat. That's the one they had to lift out with an army helicopter, right?*

Correct. And they also found the jaw of a small mammal called a docodont nearby.

Dough-cuh-dont, huh? Did they get their names from eating donuts or something?

Actually, they preferred to dine on insects, just like the docodonts sleeping in the back of the hole you are hiding in.



Where? Ick! There's a bunch of beady-eyed, whisker-faced little rats in here!

Now reeeally. Is that any way to talk about your family?

They're not my family. Although, a snack of crunchy bugs does sound mighty tempting right now. Oh my gosh, what am I saying?

What any self-respecting docodont would when it was hungry.

How do you know? Maybe they ate fruit.

There was no fruit. Fruits grow on flowering plants, and there were no flowers during the Jurassic.

No flowers, huh? Weird. Okay, so maybe they ate grass.

Grasses are also flowering plants. Flowering plants first evolved in-n-n-n . . .

W-w-w-was that an earthquake?

No, a *Diplodocus* dinosaur is walking by.

. . . and by . . . and by . . . and . . . wow, does that guy ever end?

Of course, eventually. But at 80 feet long, he's about 200 times longer than a dinky little docodont like you.

Well, all this pounding is giving me a headache. Can't you do anything about this?

I can whisk you away to the Cretaceous Period, the final time period of the dinosaurs. Our first stop is 85 million years ago, in what will one day be Colorado, but is now partly covered by an inland sea.

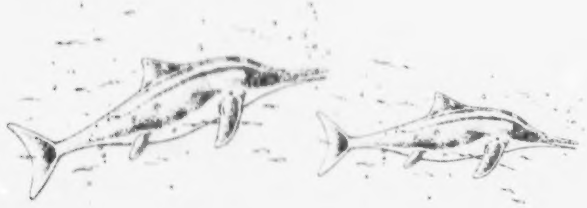
We're going to the beach? Awesome!

That is correct. The roar of the surf, the smell of that great salt air . . .

The stench of dead fish . . . yeech. Did you have to set me down in the middle of this bony carcass? This gunk better not stick to my whiskers.

Oh, I am sure the tide will rinse you off.

Yeah, off to sea probably. Hey, can my little mammal body go swimming?



I would not recommend it. There are no mammals living in the sea at this time.

Does that mean whales and porpoises are going to evolve from little land-lubbing mammals, sort of like me?

Right. But that will not occur for some time.

Hey! Wait a minute. You're pulling my paw. There's a giant dolphin in my book about the Age of the Dinosaurs.

That was probably an ichthyosaur, not a dolphin.

Oh, so it's a dinosaur.

No. There were no seagoing dinosaurs.

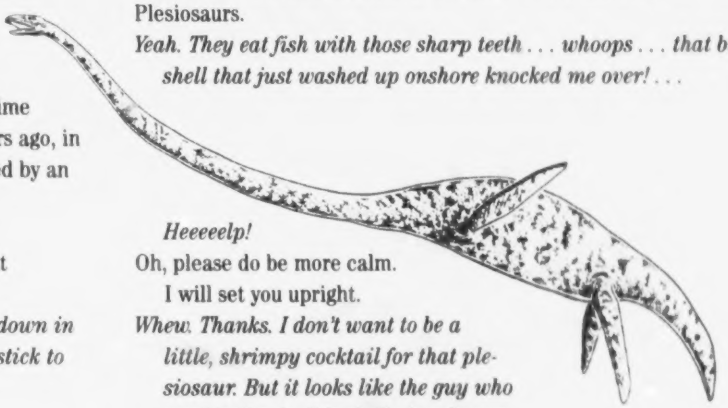
Now I know you're a few trunks short of a petrified forest. I've seen those giant sea monster dinosaurs in books all over the place.

They are not dinosaurs. They are swimming reptiles, and there are several different types out there right now.

There's one with a very long neck, like the ones hanging in the Museum of Natural History. Pleasey—uh-something.

Plesiosaurs.

Yeah. They eat fish with those sharp teeth . . . whoops . . . that big shell that just washed up onshore knocked me over! . . .



Heeeeelp!

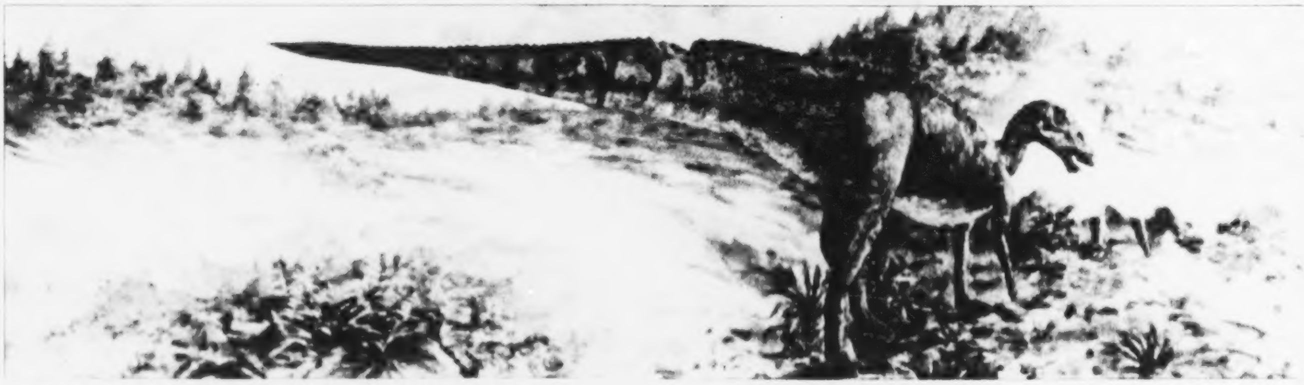
Oh, please do be more calm. I will set you upright.

Whew. Thanks. I don't want to be a little, shrimpy cocktail for that plesiosaur. But it looks like the guy who used to live in this shell already was.

Good eye. But actually, it was a dreaded mosasaur that finished this large ammonite off.

Mows-uh-saur? Is that another giant swimming reptile?

Yes. And that coiled shell belonged to an ammonite, an ancient relative of the pearly nautilus and squid.



That row of hole-punches is from the mosasaur's teeth, isn't it? Wow, it looks like a mosasaur could eat just about anything it wanted to. If I were that pterosaur flying overhead, I wouldn't get too close to the water.

Very good advice. Shall we move on now?

Sure. Being a furball on the beach isn't exactly a dream come true.

Fine, then. We are moving forward through time to 66 million years ago, where North Dakota will one day be.

This is great. The sound of the water in this creek is so soothing. Is it safe to leave this hole?

For the moment.

Great. I think I'll just scamper up this tree trunk and check things out. That way I'll have a bird's-eye view, or should I say pterosaur's-eye view?

Either would be acceptable. Birds have been around since the Jurassic. Of course, the early birds looked more like dinosaurs with feathers.

Oh yeah, birds are descended from dinosaurs.

Correct. In fact, even here in the Cretaceous, many birds still have teeth.

Teeth? Maybe putting my little plump, furry body up this tree wasn't such a good idea after all.

Well, there is that old Cretaceous saying, "The early bird gets the vermin."

Gulp. Thanks a lot. Well, I'll make my stay in this tree short. I can see a herd of duck-billed dinosaurs off in the distance. What's that smell?

Perhaps the scent of fragrant flowers, since they have finally evolved.

I don't think so. Maybe there's something dead in the grass.

Still no grass yet, sorry.

Then it has to be that big, rotting dinosaur in the oxbow of the creek. It has three horns on its face—oh, it's a Triceratops. *Easy enough . . . but what are those wild-looking, 9-foot-long dinosaurs fighting beside the creek? They have too many spikes on their heads to even count.*

Those are male *Stygimoloch* dinosaurs, vying for the attention of that female over there in the forest.

That is one intense-looking animal with an intense-sounding name. But, speaking of intense animals, I know enough to know that that's a Tyrannosaurus rex *making tracks toward us, so I'm making tracks back down to my hole. Hey, where's the docodont family?*

They're back in the Jurassic.

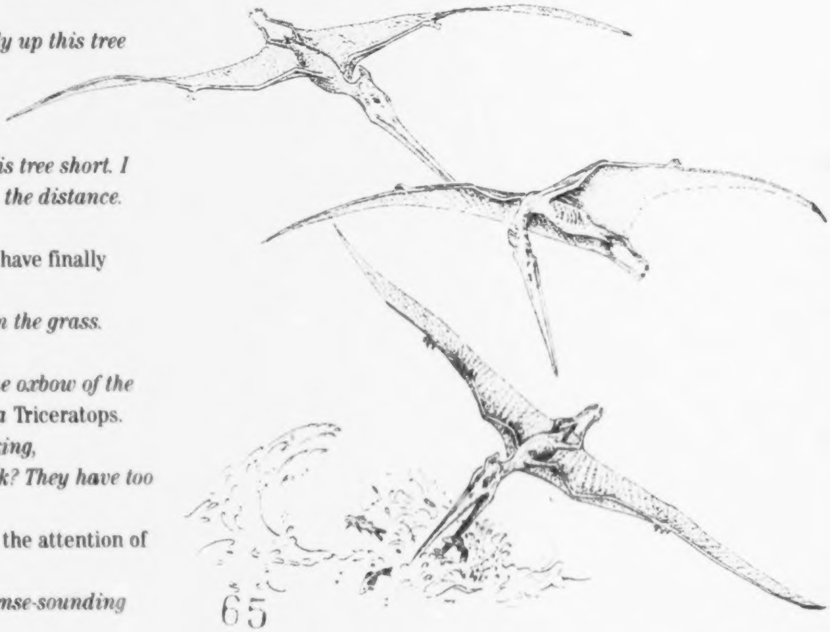
Just as well. They were giving me the creeps. Anyway, it's getting late, and I'm getting pretty sleepy. I think I'll make a wish on that big, bright shooting star and then take a little nap in my cool, dark hole. Life here in the Late Cretaceous is sure wonderful. Mmm.

It *is* a virtual wonderland, while it lasts. I will wake you up *when it is over.*

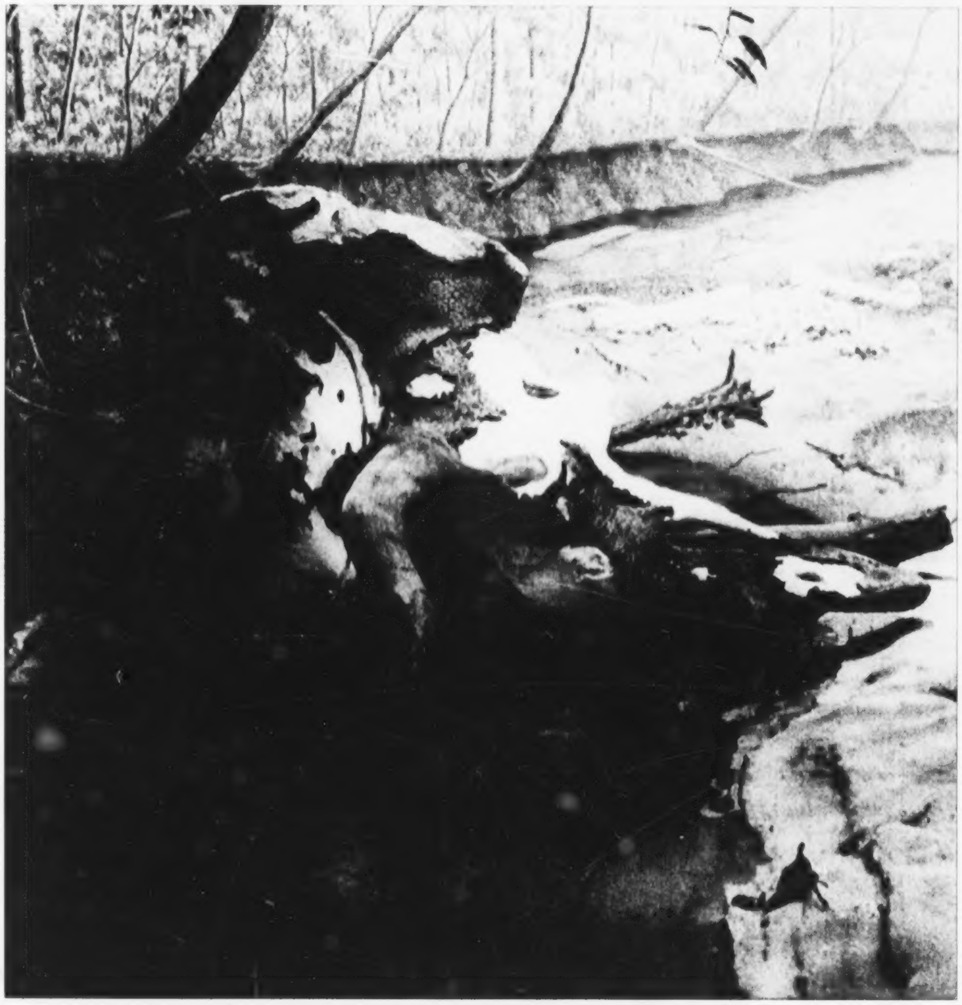
EPISODE VI: The Reigning of the Shrew

Rebecca Smith, Earth Sciences Educator

®Reprinted from *Museum Quarterly,* 1994 Fall Issue



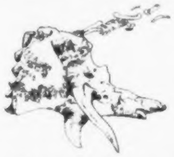
CRETACEOUS CREEKBED ENVIRORAMA



THE LAST DINOSAURS

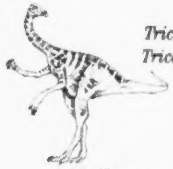
Marmarth, North Dakota

Late Cretaceous Period, 66 million years ago



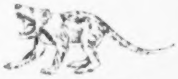
Triceratops skeleton

Triceratops horridus



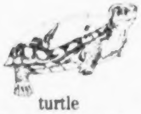
ostrich dinosaur

Ornithomimus velox



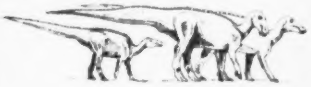
marsupial mammal

Didelphodon vorax



turtle

Neurankylus eximius

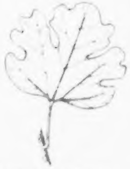


duckbilled dinosaurs

Edmontosaurus annectens

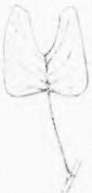
broadleaf plant

Marmarthia trinervis



small broadleaf tree

Bisonia niemii

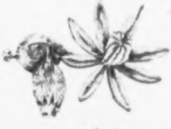


broadleaf tree

Liriodendrites bradacii

broadleaf tree

Cissites panduratus



poppy fruit

Palaeoaster inquirenda

TIME OF THE DINOSAURS

Cretaceous Creekbed

66 million years ago

UPSTREAM, BEYOND THE SKULL AND BONES OF A *TRICERATOPS*, a herd of duckbills walks along the creek.

It has been more than 200 million years since the early land animals of the Kansas Coastline.

CRETACEOUS CREEKBED ENVIRORAMA

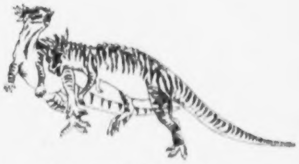
TIME OF THE DINOSAURS

Cretaceous Creekbed

66 million years ago

MALE BONY-HEADED DINOSAURS CREATE A RUCKUS, CHALLENGING each other for the attention of the female in the woods.

Dinosaurs diversified into many new and varied forms, including the world's largest land carnivore, *T. rex*.



bony-headed dinosaurs
Stygimoloch spinifer

broadleaf tree
Erlingdorfia montana

multituberculate mammal
Cimolodon nitidus

broadleaf tree
Platanites marginata

cycadophyte
Nilssonia yukonensis

fern
Onoclea sensibilis

carnivorous dinosaur
Tyrannosaurus rex

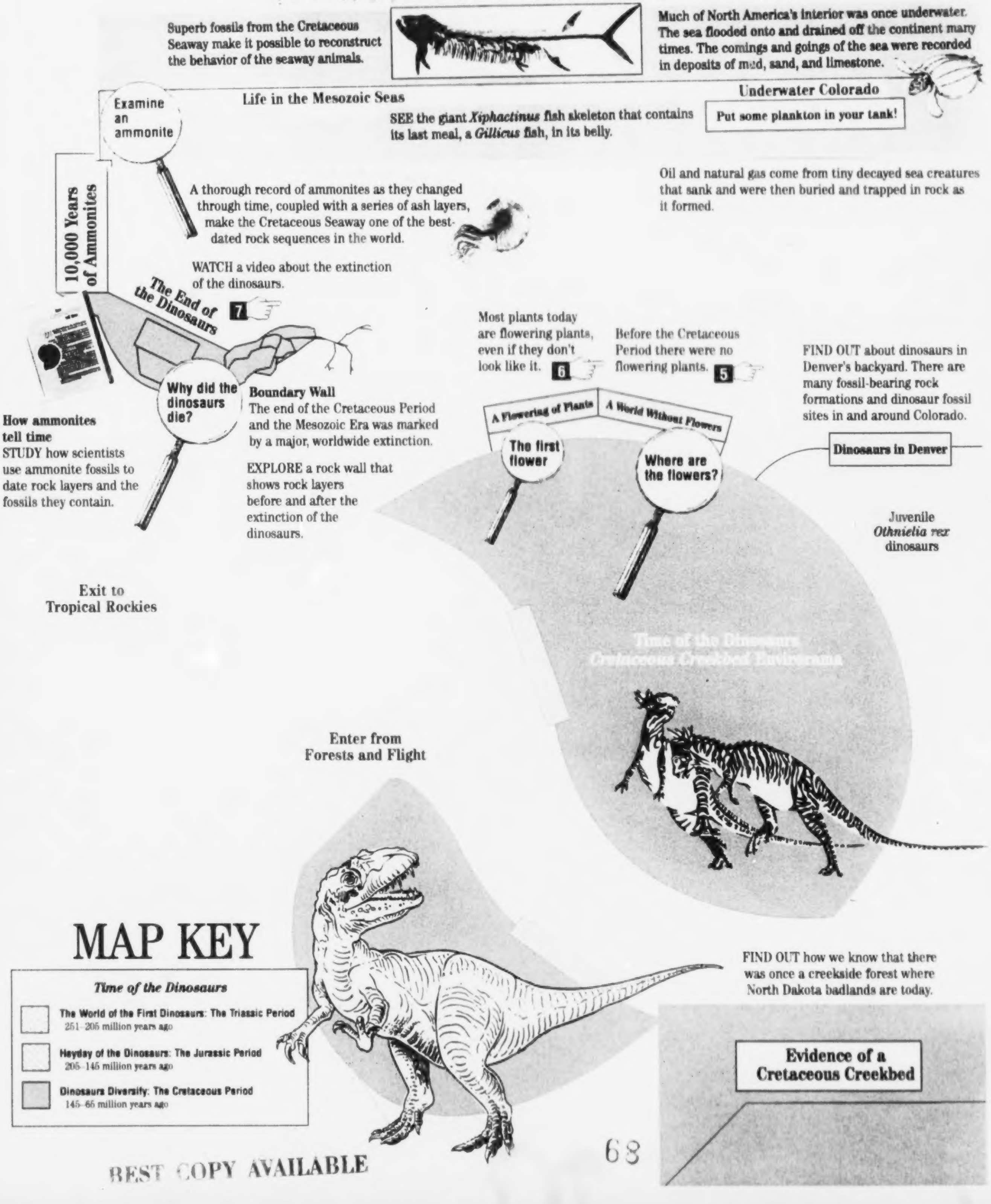
broadeaf vine
Paranymphaea hastata

broadleaf tree
Marmarthia trivialis

5. *TIME OF THE DINOSAURS* EVIDENCE AREA MAP

Flying Above the Waves, Living on the Sea Floor, Floating in the Open Water, Building Reefs, and Swimming in the Sea

LEARN about life in the Mesozoic seas, viewing spectacular fossil specimens like giant clams, ammonites (extinct relatives of the chambered nautilus), pterosaurs (flying reptiles that lived near the sea), and a mosasaur (giant swimming reptile).



Superb fossils from the Cretaceous Seaway make it possible to reconstruct the behavior of the seaway animals.

Much of North America's interior was once underwater. The sea flooded onto and drained off the continent many times. The comings and goings of the sea were recorded in deposits of mud, sand, and limestone.

Life in the Mesozoic Seas

SEE the giant *Xiphactinus* fish skeleton that contains its last meal, a *Gillicus* fish, in its belly.

Underwater Colorado

Put some plankton in your tank!

A thorough record of ammonites as they changed through time, coupled with a series of ash layers, make the Cretaceous Seaway one of the best-dated rock sequences in the world.

Oil and natural gas come from tiny decayed sea creatures that sank and were then buried and trapped in rock as it formed.

WATCH a video about the extinction of the dinosaurs.

Most plants today are flowering plants, even if they don't look like it.

Before the Cretaceous Period there were no flowering plants.

FIND OUT about dinosaurs in Denver's backyard. There are many fossil-bearing rock formations and dinosaur fossil sites in and around Colorado.

Dinosaurs in Denver

How ammonites tell time
STUDY how scientists use ammonite fossils to date rock layers and the fossils they contain.

Boundary Wall
The end of the Cretaceous Period and the Mesozoic Era was marked by a major, worldwide extinction.

EXPLORE a rock wall that shows rock layers before and after the extinction of the dinosaurs.

Juvenile *Othnielia rex* dinosaurs

Exit to Tropical Rockies

Enter from Forests and Flight

FIND OUT how we know that there was once a creekside forest where North Dakota badlands are today.

Evidence of a Cretaceous Creekbed

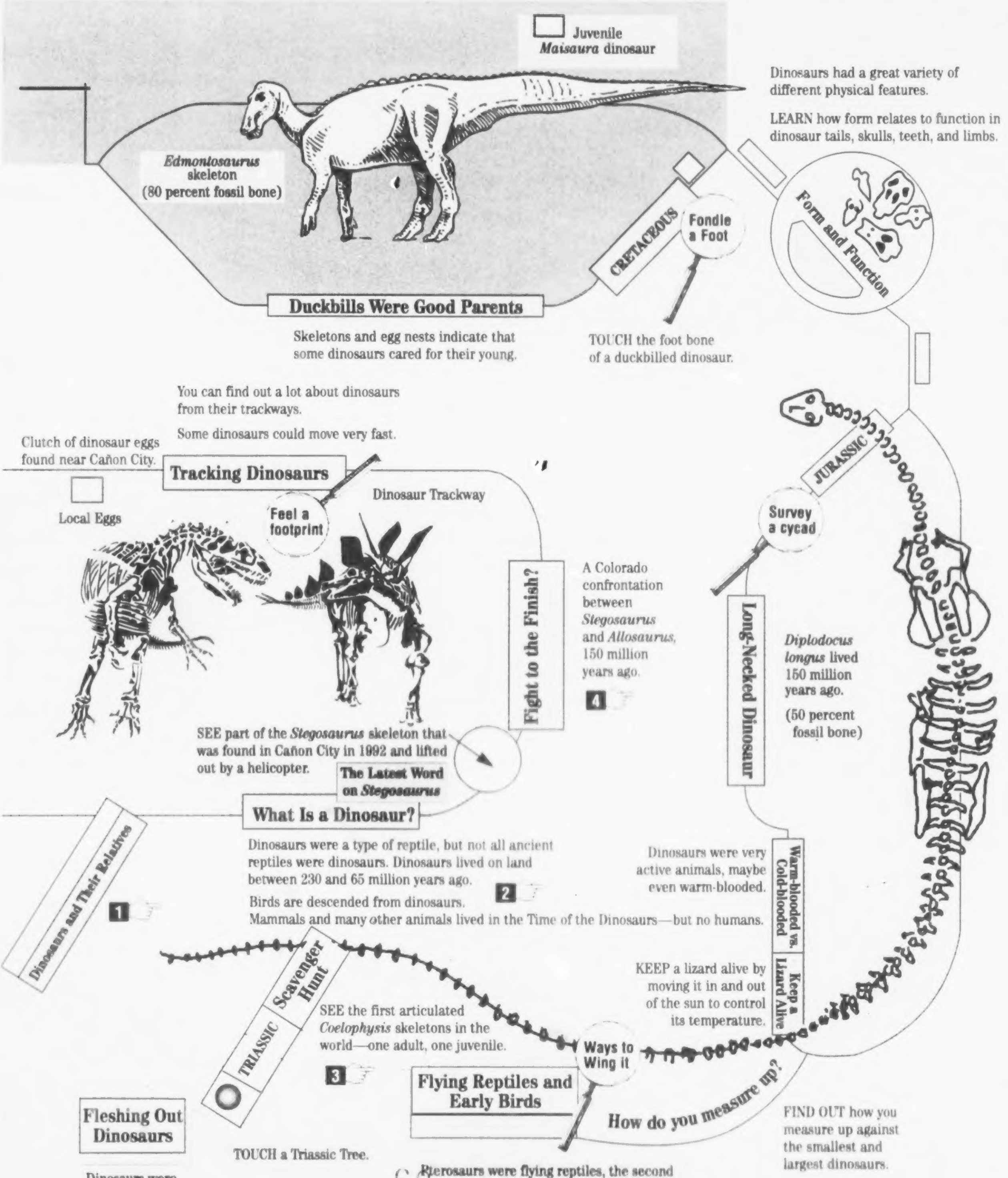
MAP KEY

Time of the Dinosaurs

☐	**The World of the First Dinosaurs: The Triassic Period** 251–206 million years ago
☐	**Heyday of the Dinosaurs: The Jurassic Period** 206–145 million years ago
▨	**Dinosaurs Diversify: The Cretaceous Period** 145–66 million years ago

BEST COPY AVAILABLE

THERE WERE A LOT OF DIFFERENT DINOSAURS OF ALL SHAPES AND SIZES. OUR KNOWLEDGE OF DINOSAURS AND THEIR LIFESTYLES HAS CHANGED A LOT IN RECENT YEARS.


☐ Juvenile *Maisaura* dinosaur
Edmontosaurus skeleton (80 percent fossil bone)
CRETACEOUS
Fondle a Foot
Form and Function
Duckbills Were Good Parents
Tracking Dinosaurs
Feel a footprint
Dinosaur Trackway
☐ Local Eggs
JURASSIC
Survey a cycad
Fight to the Finish?
Long-Necked Dinosaur
The Latest Word on *Stegosaurus*
What Is a Dinosaur?
Dinosaurs and Their Relatives
Warm-blooded vs. Cold-blooded
Keep a Lizard Alive
Scavenger Hunt
TRIASSIC
Ways to Wing it
Flying Reptiles and Early Birds
How do you measure up?
Fleshing Out Dinosaurs
1
2
3
4

Dinosaurs had a great variety of different physical features.

LEARN how form relates to function in dinosaur tails, skulls, teeth, and limbs.

Duckbills Were Good Parents

Skeletons and egg nests indicate that some dinosaurs cared for their young.

TOUCH the foot bone of a duckbilled dinosaur.

You can find out a lot about dinosaurs from their trackways.

Some dinosaurs could move very fast.

Clutch of dinosaur eggs found near Cañon City.

Tracking Dinosaurs

A Colorado confrontation between *Stegosaurus* and *Allosaurus*, 150 million years ago.

Diplodocus longus lived 150 million years ago.

(50 percent fossil bone)

SEE part of the *Stegosaurus* skeleton that was found in Cañon City in 1992 and lifted out by a helicopter.

What Is a Dinosaur?

Dinosaurs were a type of reptile, but not all ancient reptiles were dinosaurs. Dinosaurs lived on land between 230 and 65 million years ago.

Birds are descended from dinosaurs.

Mammals and many other animals lived in the Time of the Dinosaurs—but no humans.

Dinosaurs were very active animals, maybe even warm-blooded.

KEEP a lizard alive by moving it in and out of the sun to control its temperature.

SEE the first articulated *Coelophysis* skeletons in the world—one adult, one juvenile.

Flying Reptiles and Early Birds

FIND OUT how you measure up against the smallest and largest dinosaurs.

Fleshing Out Dinosaurs

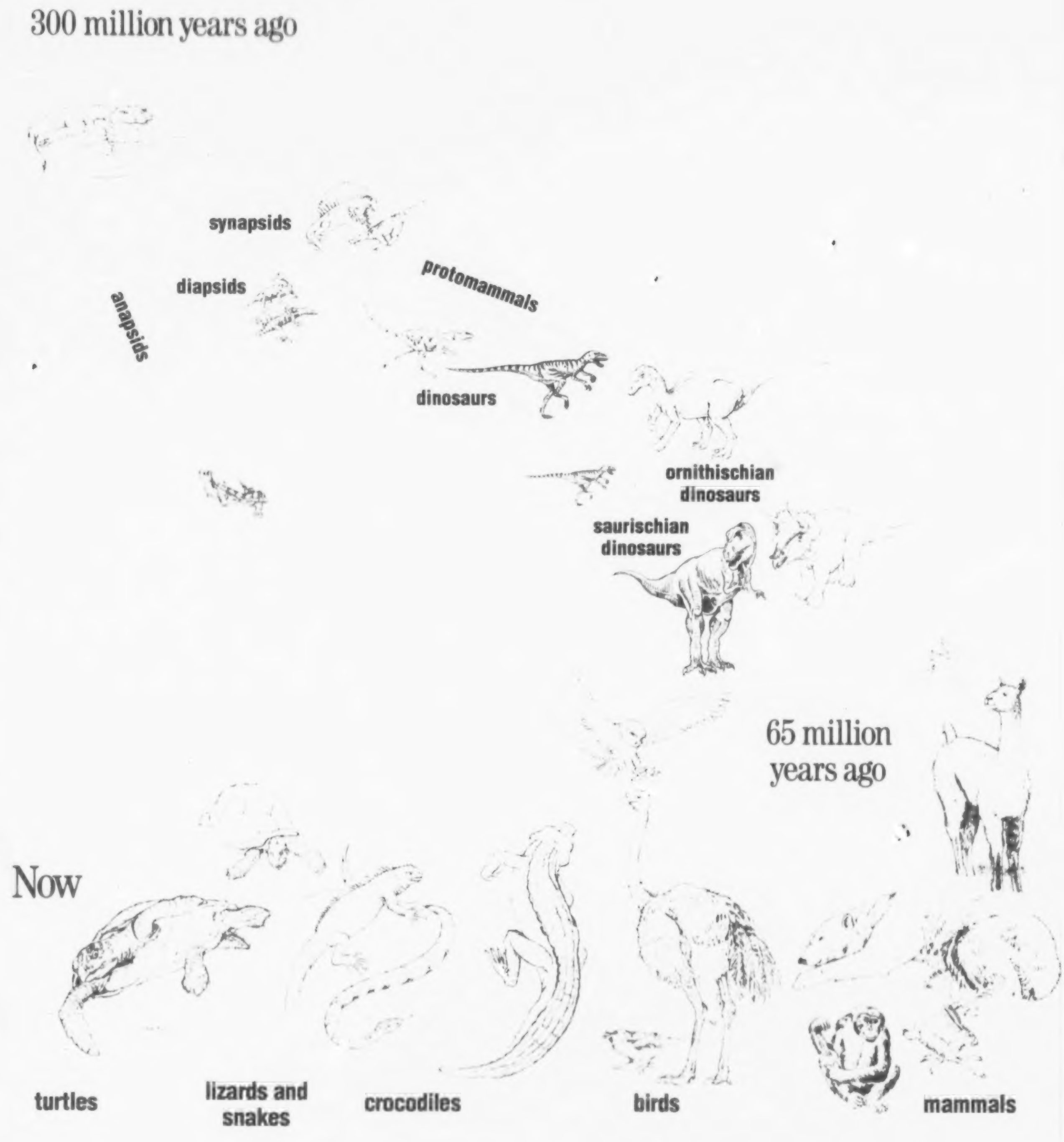
TOUCH a Triassic Tree.

Dinosaurs were flesh-and-blood animals, not just skeletons.

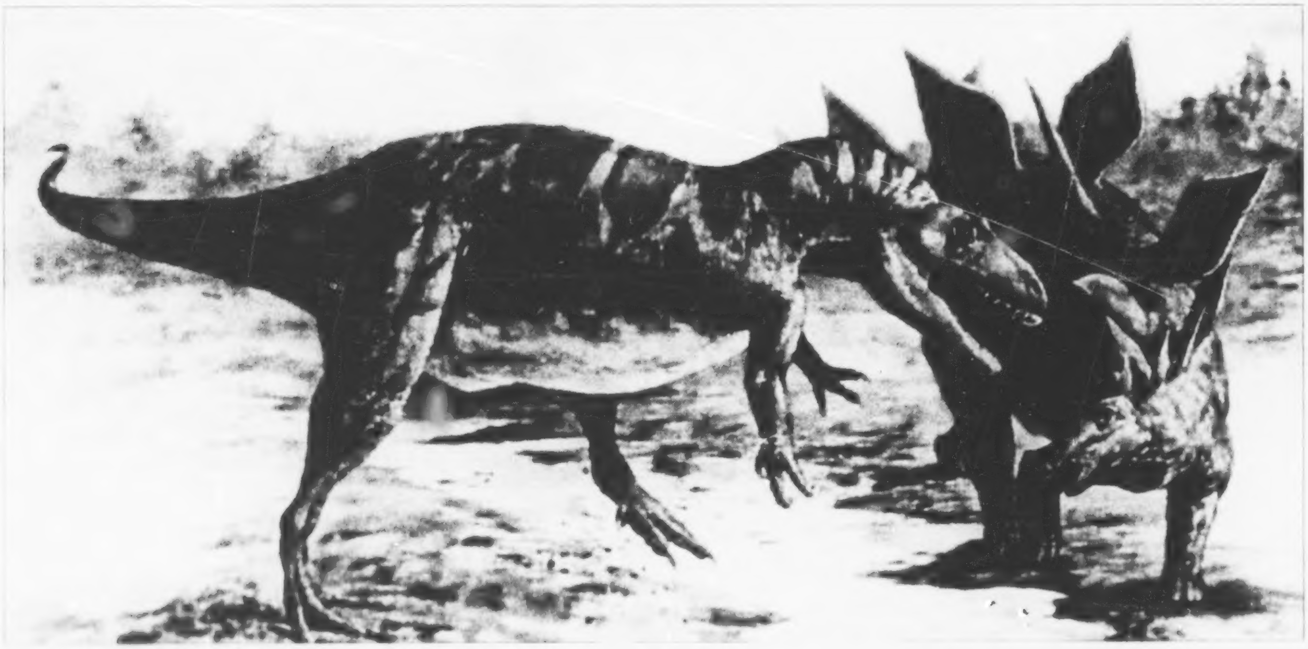
Pterosaurs were flying reptiles, the second kind of animal that learned to fly.
Birds were the third kind of flying animal.
They evolved from dinosaurs, not pterosaurs.

BEST COPY AVAILABLE

DINOSAURS AND THEIR RELATIVES


300 million years ago
synapsids
diapsids
anapsids
protomammals
dinosaurs
ornithischian dinosaurs
saurischian dinosaurs
65 million years ago
Now
turtles
lizards and snakes
crocodiles
birds
mammals

WHAT IS A DINOSAUR?

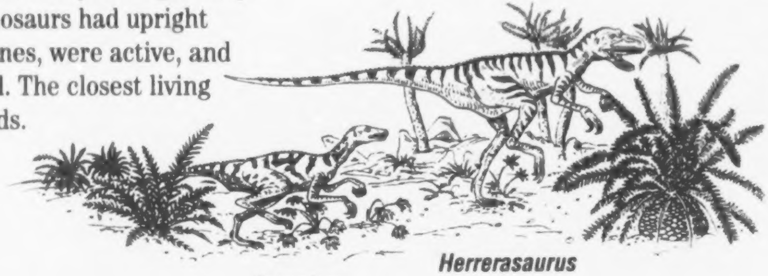


Allosaurus

Stegosaurus

NOT EVERYTHING THAT IS BIG AND EXTINCT is a dinosaur! Dinosaurs were reptiles that lived on land between 230 and 65 million years ago. They didn't fly or live in water. Dinosaurs had upright posture, specialized ankle bones, were active, and may have been warm-blooded. The closest living relatives to dinosaurs are birds.

There were two main groups of dinosaurs based on hip structure—**ornithischians,** such as *Stegosaurus*, and **saurischians,** such as *Allosaurus.*



The earliest known dinosaur fossils are from South America.

Mammals in the Time of Dinosaurs

When you think about dinosaurs, you probably imagine that they were the only animals around. But there were plenty of others, including mammals. Mammals today are furry, warm-blooded animals that nurse their young.

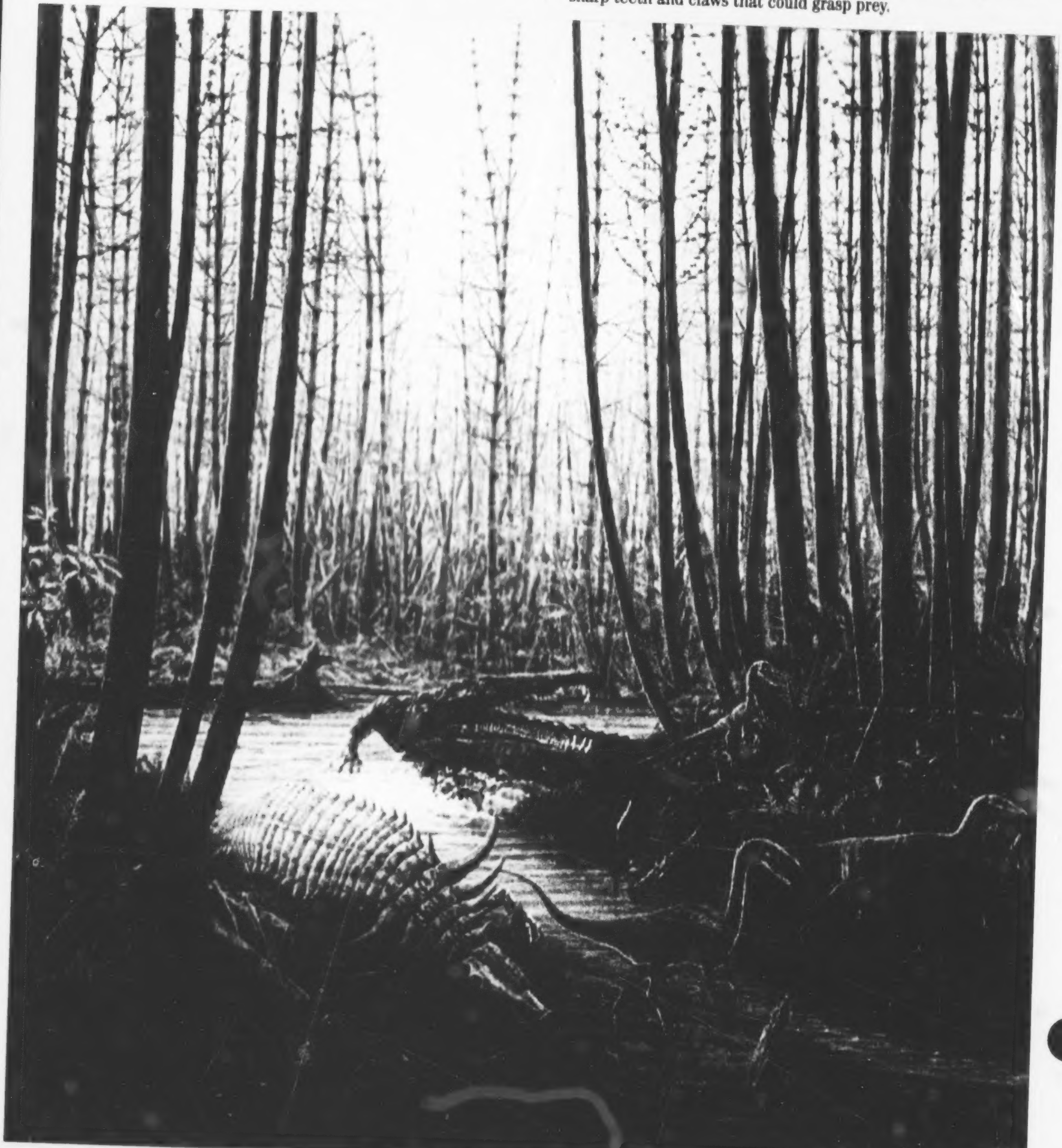
The first mammals were small, and lived mostly in the ground cover on the forest floor.

Dinosaurs had stronger teeth than their ancestors.

3 SCAVENGER HUNT

These *Coelophysis* dinosaurs scatter from a carcass they've been scavenging, scared off by the large phytosaur coming around the bend. The dead animal is *Desmatosuchus*, a plant-eating reptile.

Coelophysis was one of the earliest dinosaurs in North America. These small dinosaurs with hollow bones and slender bodies were built for speed. They were meat-eating hunters with many small, sharp teeth and claws that could grasp prey.



BEST COPY AVAILABLE

4 ☞

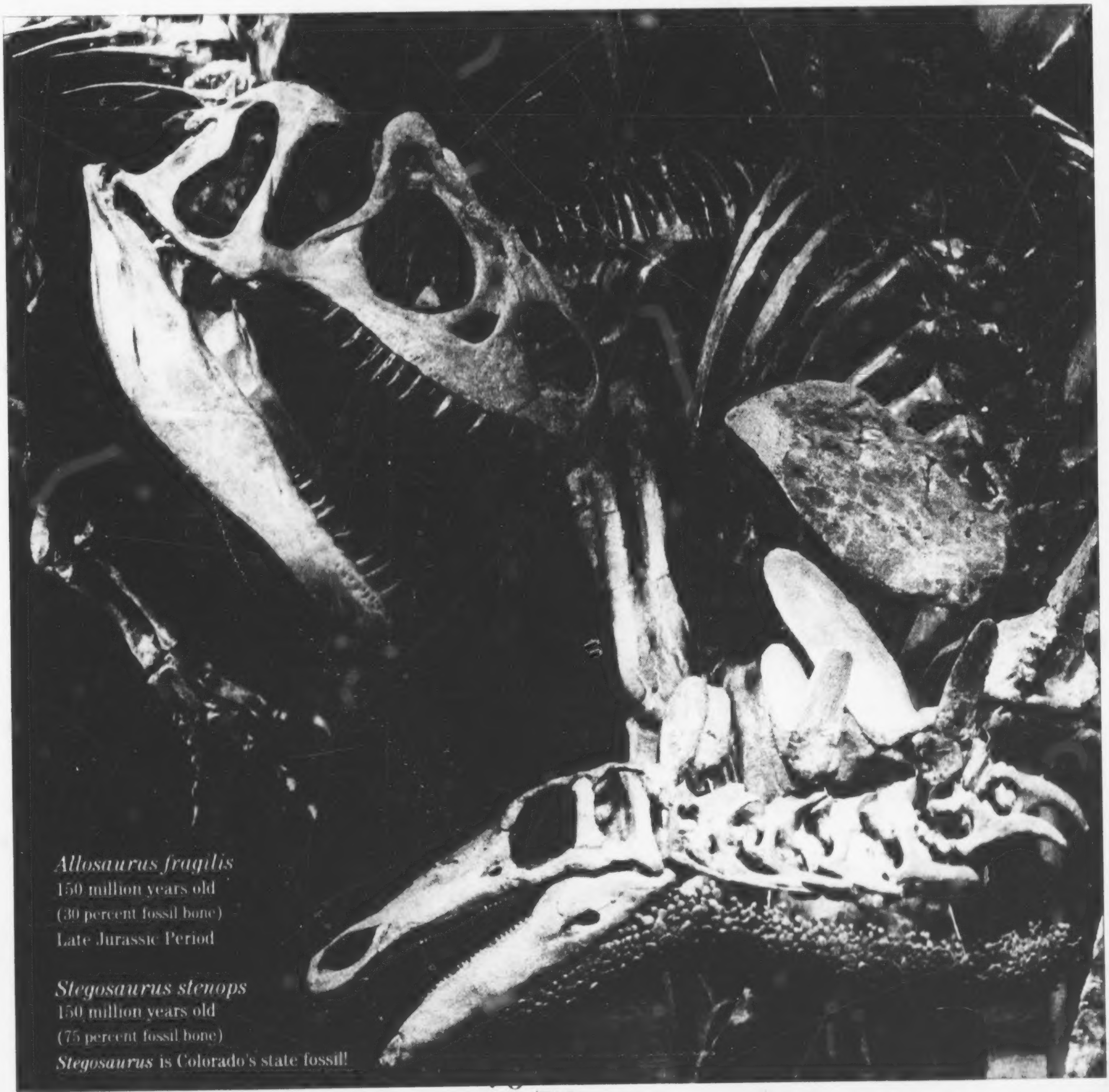
FIGHT TO THE FINISH?

You might think that the outcome of this fight is a foregone conclusion. After all, Allosaurus *was one of the most fearsome predators of its day, and* Stegosaurus *was more likely to be prey. But the solidly built* Stegosaurus *was well equipped to defend itself.*

Notice the powerful jaws and many sharp teeth. *Allosaurus* was a carnosaur, or "flesh-eating reptile." *Allosaurus's* long legs, each with three spreading, clawed toes, were extremely strong. Its better-known relative—*Tyrannosaurus rex*—didn't come along for another 80 million years. You can tell them apart because *Allosaurus* is smaller, and has three fingers on its hand—*Tyrannosaurus* has only two.

The word *Stegosaurus* means "lizard with a roof." *Stegosaurus* was an armored, plant-eating dinosaur. Staggered rows of plates along its back made the animal look bigger than it was, and may have helped the animal control its body heat or attract a mate.

Did you notice the bony patches—called scutes—under this animal's neck? They protected the throat. *Stegosaurus* carried its tail high, so its spikes could be used as weapons.



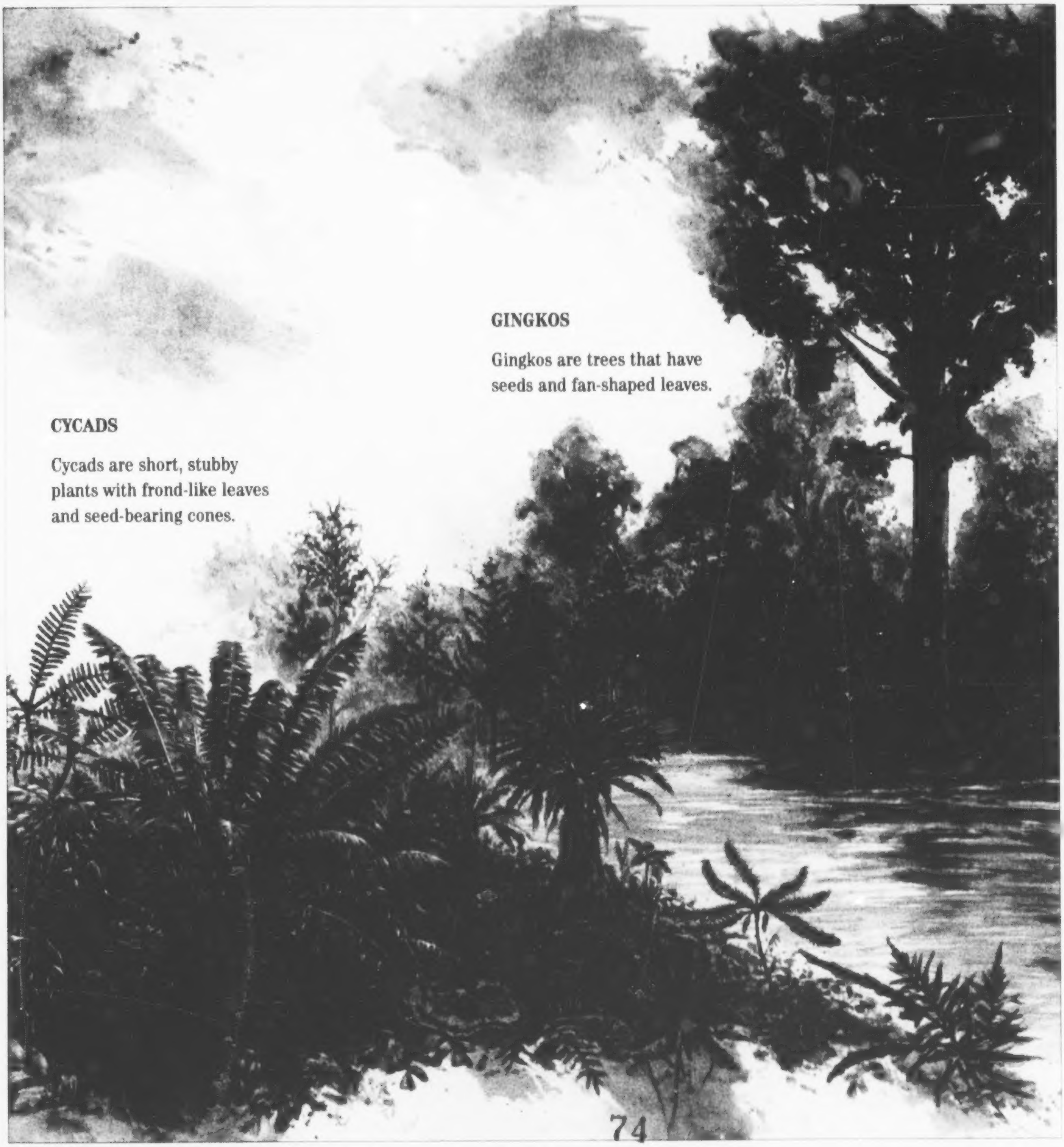
Allosaurus fragilis
150 million years old
(30 percent fossil bone)
Late Jurassic Period

Stegosaurus stenops
150 million years old
(75 percent fossil bone)
Stegosaurus is Colorado's state fossil!

5 ☞ A WORLD WITHOUT FLOWERS

UNTIL 130 MILLION YEARS AGO, THERE WERE NO flowers. Earth's vegetation was made up of ferns, conifers, horsetails, gingkos, cycads, and other seed plants.

PLANTS HAD ALREADY MADE ONE BIG TRANSITION—development of seeds. The next wave of change would be evolution of flowering plants.



GINGKOS

Gingkos are trees that have seeds and fan-shaped leaves.

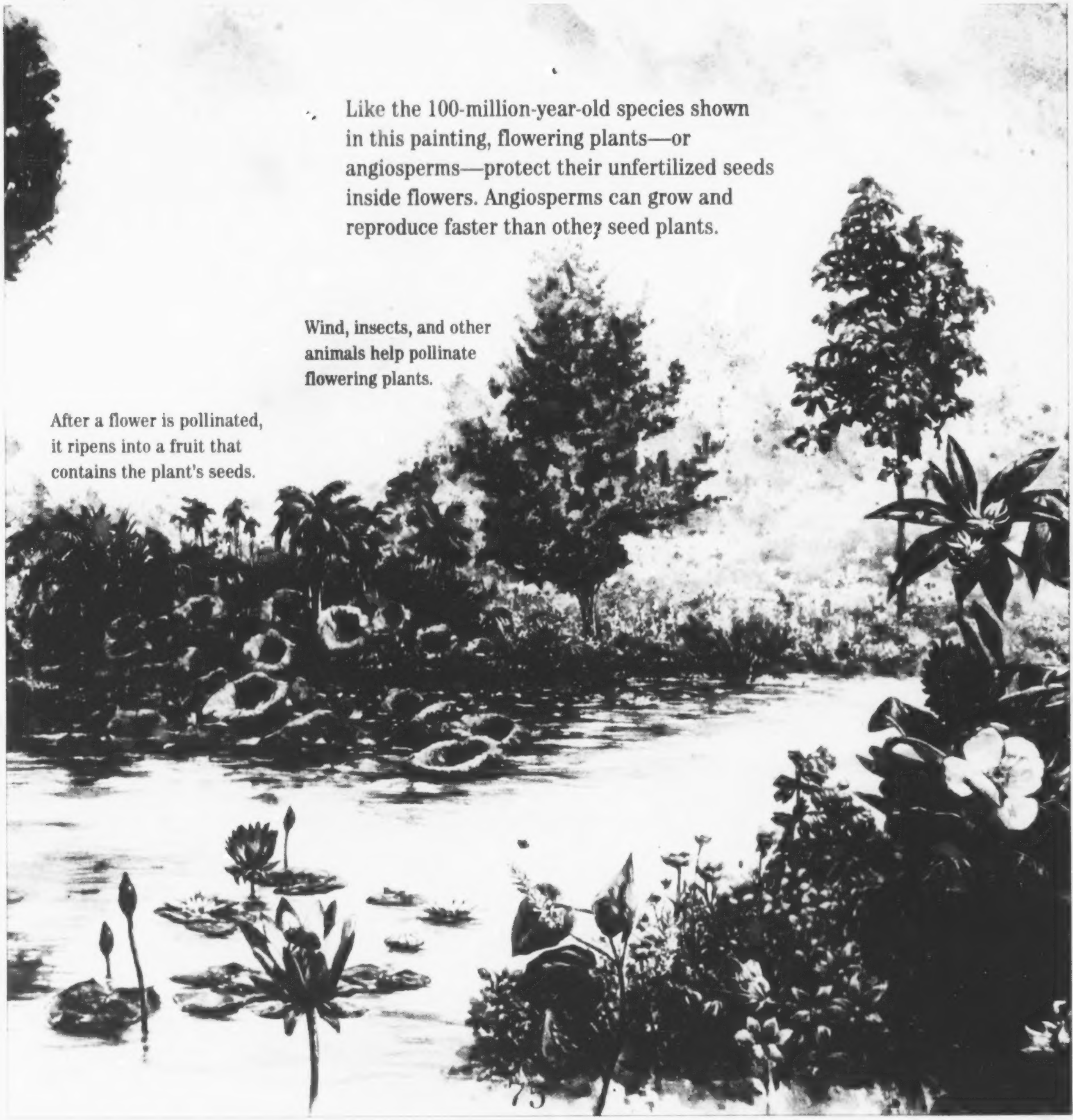
CYCADS

Cycads are short, stubby plants with frond-like leaves and seed-bearing cones.

A FLOWERING OF PLANTS

FLOWERING PLANTS COME IN ALL SHAPES AND SIZES. Not all flowering plants have showy blossoms. Grasses, palm trees, oak trees, and cactus—in fact most of the plants in today's world—are flowering plants.

FLOWERING PLANTS FIRST APPEARED ABOUT 130 MILLION YEARS AGO. By the end of the Cretaceous Period, they had become the most abundant plants on Earth.



Like the 100-million-year-old species shown in this painting, flowering plants—or angiosperms—protect their unfertilized seeds inside flowers. Angiosperms can grow and reproduce faster than other seed plants.

Wind, insects, and other animals help pollinate flowering plants.

After a flower is pollinated, it ripens into a fruit that contains the plant's seeds.

THE END OF THE DINOSAURS

A chronicle of the end of the Cretaceous

by Kirk R. Johnson

Curator of Paleontology

So what is this thing called the Cretaceous-Tertiary, or K-T, boundary? The Cretaceous Period began about 144 million years ago and ended 65 million years ago. It was followed by the Tertiary Period. So the Cretaceous-Tertiary boundary is that instant in time when the Cretaceous ended and the Tertiary began. We call it a boundary because the subdivisions of geological time are often defined by the sedimentary rocks that were deposited during those times. Thus, Cretaceous rocks are overlain by Tertiary rocks, and the point of contact is the boundary. What makes the Cretaceous-Tertiary boundary significant is that dinosaur fossils are found in Cretaceous rocks, but they're not found in the overlying Tertiary rocks. But what happened at the end of the Cretaceous to cause the dinosaur disappearance?

Theories explaining the extinction of the dinosaurs have been a scientific fad ever since Richard Owen first named dinosaurs back in 1841. There have been dozens of theories, most based on pure speculation and most not very testable. For instance, how could you prove that dinosaurs died from the flu or that they passed on because they were world-weary?

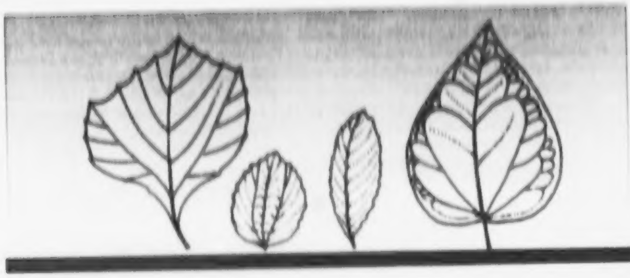
SO CLOSE YOU CAN TOUCH IT: AT THIS OUTCROP NEAR MARMARTH, NORTH DAKOTA, KIRK JOHNSON POINTS TO THE BOUNDARY BETWEEN THE CRETACEOUS AND TERTIARY PERIODS; DINOSAUR FOSSILS ARE FOUND BELOW THE LINE, BUT NOT ABOVE IT.

In 1980, a new theory was proposed. A team of scientists, led by geologist Walter Alvarez and his father, Nobel Prize–winning physicist Luis Alvarez, offered that the impact of an asteroid or comet caused the major extinctions at the end of the Cretaceous. They had discovered unusually high concentrations of a platinum-group metal known as iridium at the K-T boundary at three places: Italy, Denmark, and New Zealand. Iridium is commonly found in extraterrestrial debris such as meteorites as well as deep beneath the Earth's crust, but it is rare on the surface of the Earth. The Alvarezes suggested that an asteroid 6 miles (10 km) in diameter had collided with the Earth, throwing up huge clouds of dust. These dust clouds would have kept the sun's light from reaching the Earth's surface, causing the deaths of plants, then herbivorous animals, and finally the carnivorous animals. Basically, the scientists proposed that this impact caused the collapse of the Earth's food chains.

What made this theory different from the others was that it was testable. If the Alvarezes were correct, scientists should be able to visit the K-T boundary anywhere in the world and discover physical evidence of the impact precisely at the level marked by the extinctions.

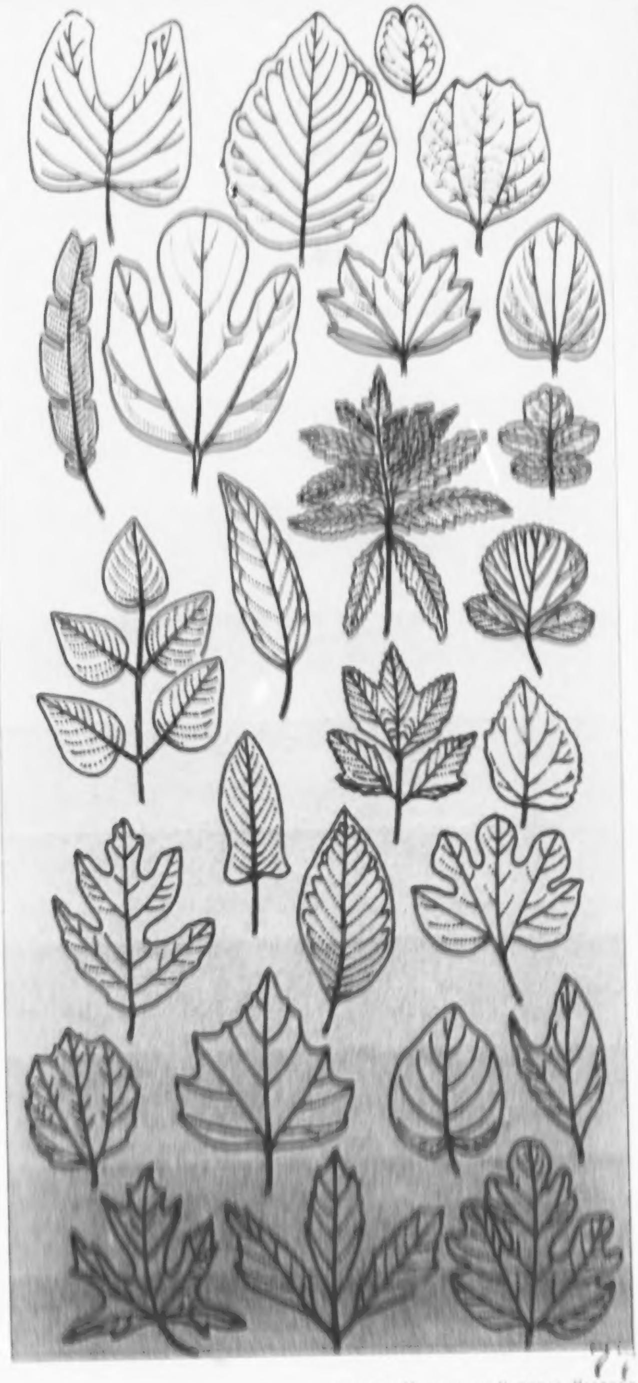
Scientists are skeptical people. They were not about to believe in this dinosaur extinction theory if the iridium layer wasn't directly associated with the last dinosaur fossils. Dinosaur fossils are not so abundant, but other fossils found with dinosaurs that similarly failed to survive the boundary are more common. Also decimated were the flying pterosaurs on land and the marine reptiles, ammonites, and plankton in the sea. The plants that lived with the dinosaurs provide the most profound evidence of the extinction on land. Like modern plants, they produced huge amounts of pollen that readily fossilized. A tiny sample of rock can be dissolved in acid to yield thousands of pollen grains, and the grains can be used to define the K-T boundary by their diversity and number in terrestrial rocks.

In 1981, Bob Tschudy from the U.S. Geological Survey (USGS) in Denver and scientists from the Los Alamos National Laboratories announced that, by sampling pollen and testing for iridium,



THE DIAGRAM TO THE LEFT COMPARES PLANTS FROM THE END OF THE CRETACEOUS WITH THOSE FROM THE EARLY TERTIARY, OR PALEOCENE. CRETACEOUS LEAVES, BELOW THE BOUNDARY, ARE DIVERSE AND VARIED WHILE PALEOCENE ONES, ABOVE THE BOUNDARY, REPRESENT THE FEW SURVIVORS OF A MASS EXTINCTION.

THIS SANDSTONE SLAB, BELOW, SHOWS LATE CRETACEOUS LEAF FOSSILS AND PLASTIC RE-CREATIONS FOR THE *PREHISTORIC JOURNEY* EXHIBITION; MOST OF THESE SPECIES DID NOT SURVIVE THE K-T BOUNDARY EXTINCTIONS.



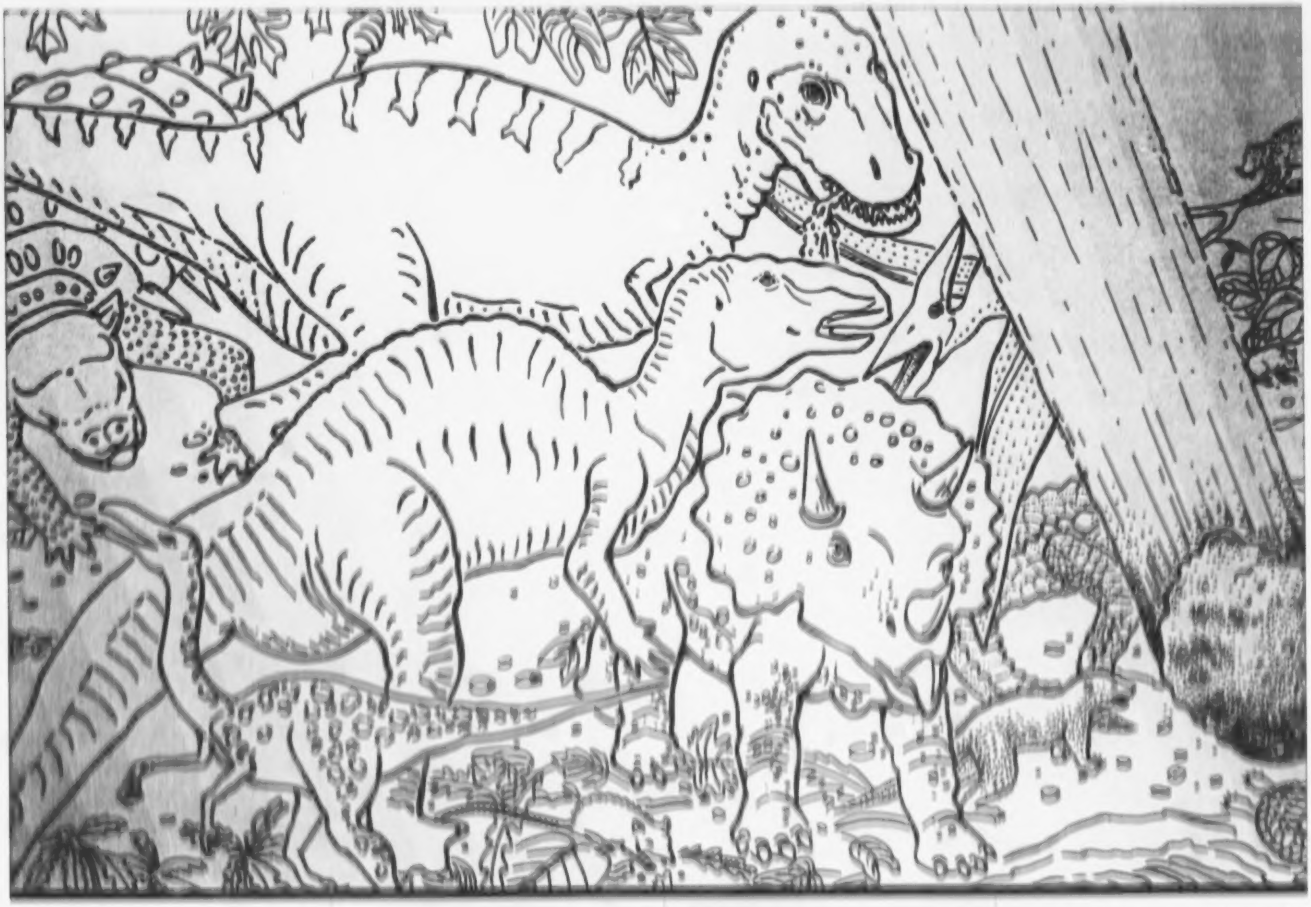
they found evidence of the impact layer at a terrestrial K-T boundary in New Mexico. Later that year, the Alvarezes themselves located iridium at the K-T boundary in the famous Hell Creek fossil beds of Montana. Here, the last dinosaurs lay just below the iridium layer.

In 1981, I was minding my own business, collecting fossil plants in early Paleocene–epoch rocks of North Dakota. The Paleocene is the first part of the Tertiary Period, so early Paleocene deposits are immediately above the K-T boundary. In North Dakota the Late Cretaceous rocks lie just below the Paleocene rocks, so all you have to do to cross the K-T boundary is literally walk down the hill. I, like many other paleontologists, was skeptical of this outlandish theory that attributed the demise of our beloved dinosaurs to some science fiction asteroid. I decided that I would use plant fossils to test the Alvarez theory. After all, plants are the base of the food chain and their extinction was a critical part of the Alvarez theory. My previous work on Paleocene leaves gave me an idea what was alive after the dinosaurs died; my new goal was to discover the nature of the environment in which they lived.

I began searching for Late Cretaceous plant fossils and found that they were quite rare. Following tips from a geologist friend, David Fastovsky, and my own hunch, I returned to my sites near Marmarth in the southwest corner of North Dakota. Here, the Hell Creek Formation is superbly exposed in a series of badlands carved by the Little Missouri River, and dinosaur fossils are common finds in the gray hills. The Hell Creek Formation is overlain by the more recent Fort Union Formation. The K-T boundary lies very near the contact of the two formations.

And here I began to prospect for fossil plants. Hunting for fossil plants involves walking around in the badlands and digging hundreds of holes in the hills. Eventually, persistence paid off and I began to find fossils.

By 1988, a new challenge to the Alvarez theory had been raised. Chuck Officer, a Dartmouth professor, was convinced that



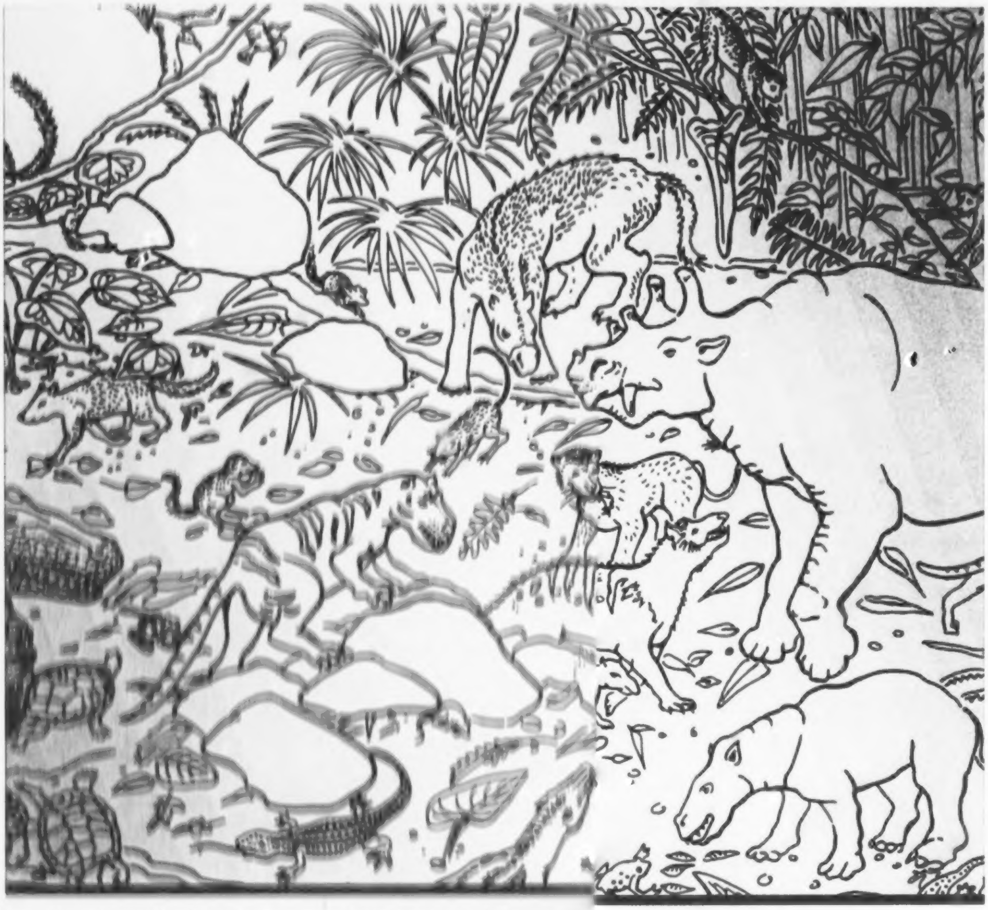
volcanism, not an asteroid, was responsible for the iridium anomaly and the extinctions. He noted that huge lava flows in western India, known as the Deccan Traps, had their origin at about the time of the K-T boundary. Moreover, the gases emitted by the volcano Kilauea on Hawaii had been shown to have elevated levels of iridium, suggesting that Officer's idea had some merit. What was needed was some sort of test to separate volcanic debris from asteroidal debris.

This test was provided by Bruce Bohor of the USGS in Denver. He noted that energy levels of impacts were much higher in asteroid collisions than in volcanic eruptions. He showed that the crystalline lattices of quartz and other mineral grains were highly distorted or shocked by asteroid impacts but not by volcanoes. All that remained was to locate shocked mineral grains in the iridium-bearing K-T boundary layer. In 1984, Bohor found such grains at a K-T site in Wyoming and the volcano theory began to fade into the woodwork.

SO SMALL, YET SO BIG: SINCE MOST PLANTS WENT EXTINCT WITH THE DINOS, ABUNDANT MICROSCOPIC POLLEN GRAINS HELP DEFINE THE K-T BOUNDARY.

SHOCKED QUARTZ GRAINS WITH MULTIPLE SHOCK PLANES HAVE BEEN RECOVERED ONLY FROM ASTEROID IMPACT CRATERS AND NUCLEAR TEST SITES.

By this time, I was beginning to think that there might be something to this asteroid theory after all. I decided to run a test of my own. At a site named Pyramid Butte in southwestern North Dakota, I carefully sampled a continuous sequence of rock across the interval that contained the K-T boundary. I split the samples and sent one half to Carl Orth at the Los Alamos National Labs who tested the samples for iridium. I sent the other half to Douglas Nichols at the USGS. Doug used pollen analysis to pinpoint the extinction horizon to within a few centimeters. The results came back, and I was amazed to see that a spike of iridium occurred at precisely the level where a high percentage of the pollen grains became extinct. A few months later we were able to find shocked mineral grains—evidence of an asteroid impact—in that same layer. My skepticism began to fade.



THIS TIME-LAPSE ILLUSTRATION COMPRISES A 15-MILLION-YEAR SPAN, FROM LEFT TO RIGHT, SHOWING BEFORE, DURING, AND AFTER THE ASTEROID STRIKE THOUGHT TO HAVE SNUFFED OUT MOST LARGE FORMS OF LIFE, INCLUDING THE DINOSAURS. LEFT OF THE ASTEROID STRIKE SHOWS THE FINAL MOMENTS WHEN DINOSAURS RULED THE WORLD 65 MILLION YEARS AGO. THE LARGER DINOSAURS PICTURED ARE TYRANNOSAURUS REX, TRICERATOPS, STRUTHIOMIMUS, EDMONTOSAURUS AND (A PARTIAL) ANKYLOSAUR. PTERODACTYL IS ALSO SHOWN.

TO THE RIGHT OF THE ASTEROID IS THE PALEOCENE EPOCH, SANS DINOSAURS, WHEN MAMMALS BEGAN THEIR GREAT DIVERSIFICATION AND GROWTH. MOST OF THESE ODD, PRIMITIVE CREATURES WERE LATER TO BECOME EXTINCT—ONE EXCEPTION BEING THE TAPIR, THE LARGE, FURRY BEAST PICTURED NEAR THE TOP OF THE RIGHT SIDE. NOTE THAT A FEW ANIMALS, SUCH AS THE CROCODILE AND TURTLES, SURVIVE THE ASTEROID STRIKE AND APPEAR ON BOTH SIDES.

I continued to collect fossil leaves. By 1988, I had collected more than 11,000 fossil leaves from 87 separate quarry sites above and below the K-T boundary. I was beginning to have enough data to see patterns, and the patterns were surprising. More than 80 percent of the fossil plant species that I found just below the boundary were not present immediately above it. I was seeing some of the most dramatic and convincing evidence for a mass extinction of plant life ever recorded. By the end of the 1988 field season, I was convinced that Walter and Luis Alvarez had come up with a pretty good theory.

So what was the pattern? The Hell Creek Formation is rich in fossils and provides a clear picture of life at the very end of the Cretaceous. This is the formation that first yielded *Tyrannosaurus rex* and a host of our other favorite dinosaurs: the three-horned *Triceratops*, the duck-billed *Edmontosaurus*, the bone-headed *Pachycephalosaurus*, the ostrich dinosaur *Struthiomimus*, the armored ankylosaurs, as well as a variety of small mammals, turtles, crocodiles, lizards, and other vertebrates. The plant life of the Hell Creek Formation includes more than 200 different leaf types—clearly a diverse and healthy subtropical ecosystem. The Fort Union Formation of the early Tertiary, in contrast, has no dinosaurs, only small mammals, small crocodilians, turtles, and a handful of other beasts. The vegetation was of very low diversity. Where a good Late Cretaceous leaf locality would yield as many as 60 plant species, the typical Paleocene site had less than 10. The dramatic reduction of plant and animal life and the presence of the iridium-bearing layer strongly suggested a cause-and-effect relationship.

Still, one piece of the K-T puzzle remained missing. If there had been an asteroid impact, where was the crater? Where was the "smoking gun"? The Alvarezes had predicted a crater at least 62 miles (100 km) in diameter. After more than a decade of searching, the only result was a small, 22-mile (35-km) crater in Iowa. Sixty-five million years is a long time, more than enough time to bury or erode a crater. Alan Hildebrand, a Canadian geologist, began a systematic search for the crater. He reasoned that the larger shocked mineral grains would fall out closer to the crater. By 1990, the iridium and shocked mineral-bearing layer had been found at more than 100 sites worldwide. Denver geologist Glen Izett had plotted up the sizes of the grains, and it became apparent that the impact had occurred somewhere near North America. In 1991, by pure persistence, Hildebrand finally discovered a buried crater on the northwest coast of Mexico's Yucatan Peninsula. When the measurements had been made, the Chicxulub crater turned out to be at least 112 miles (180 km) in diameter, the largest crater ever found on Earth. Radiometric dating of melt glass from the core of the crater gave an age of 65 million years, the age of the K-T boundary. The smoking gun had been found!

EST COPY AVAILABLE

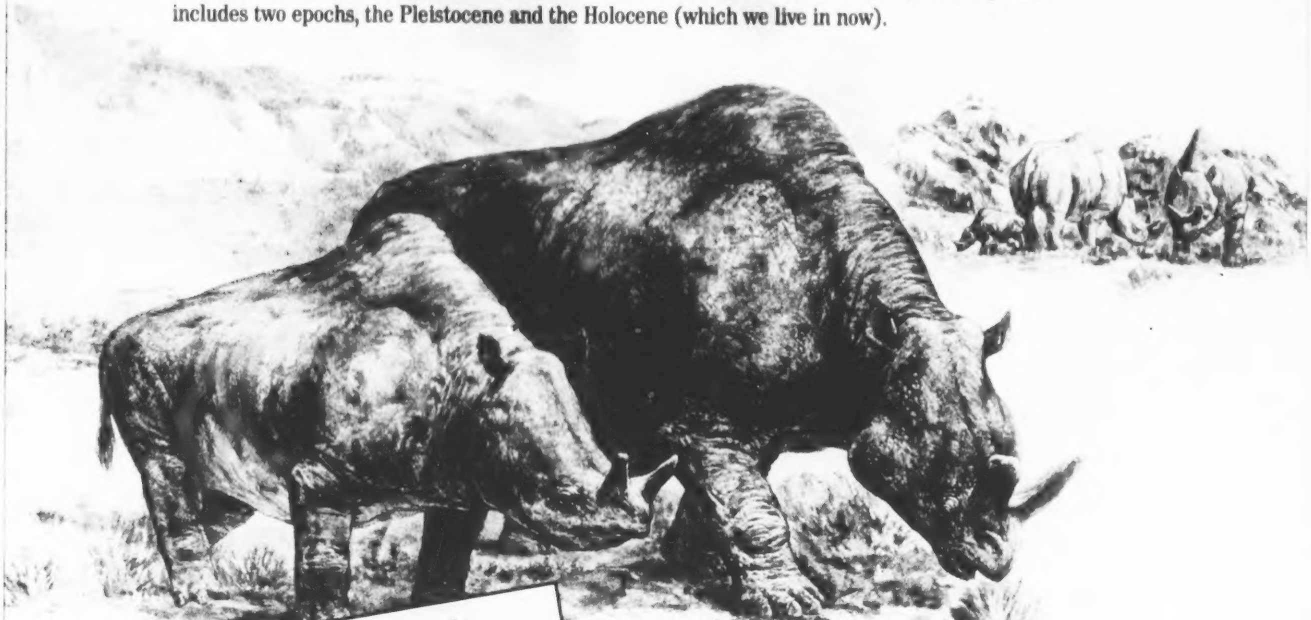
REPRINTED FROM MUSEUM QUARTERLY / SPRING 1995

CENOZOIC ERA

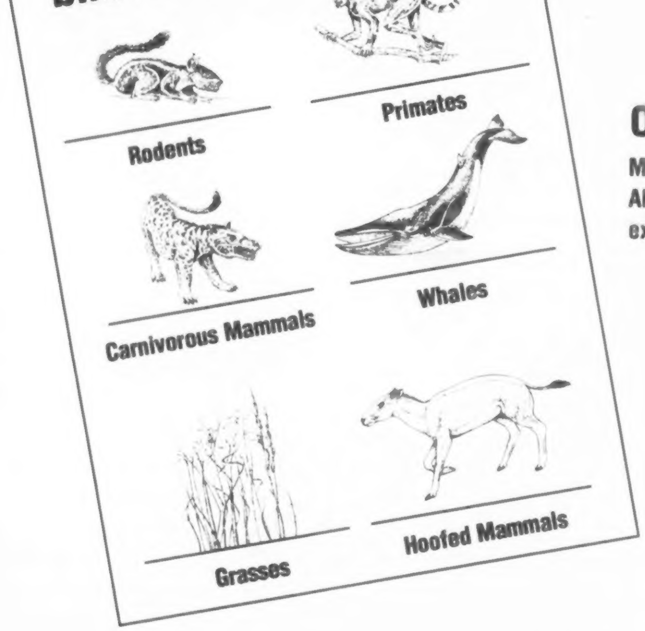
65 MILLION YEARS AGO TO THE PRESENT

The Cenozoic Era lasted 65 million years. Changing climate patterns and the death of many previous species of animals and plants paved the way for the period of time that scientists call the Cenozoic Era.

The Cenozoic Era includes two time periods, which are subdivided into epochs. The Tertiary Period includes the Paleocene, Eocene, Oligocene, Miocene, and Pliocene Epochs. The Quaternary Period includes two epochs, the Pleistocene and the Holocene (which we live in now).



birth announcements

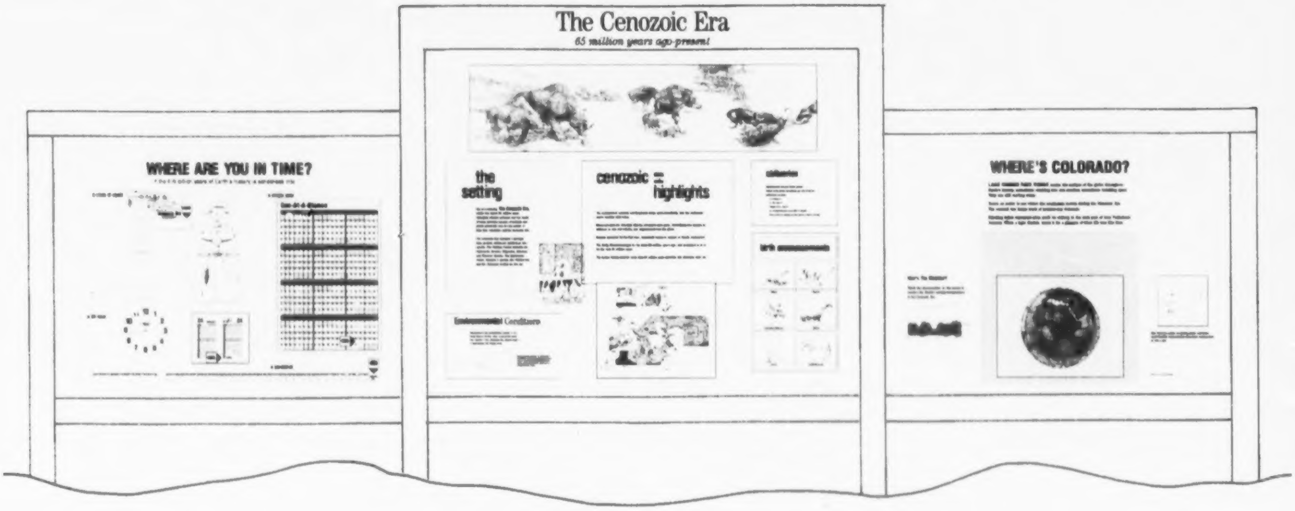


obituaries

Most Mesozoic land and marine species
Almost all the plants and animals you saw in the last exhibit area are gone:

All dinosaurs
All pterosaurs
Most marine reptiles
All ammonites and many other mollusks
Nine out of 10 species of land plants in North America

CENOZOIC TIME STATION


The Cenozoic Era
65 million years ago-present
WHERE ARE YOU IN TIME?
the setting
cenozoic highlights
WHERE'S COLORADO?

CENOZOIC ERA HIGHLIGHTS

Mammals stole the limelight after the dinosaurs were gone, diversifying into species as different as rats and whales, and migrating all over the globe.

The continents of Laurasia and Gondwana broke apart completely, into the continents you're familiar with today.

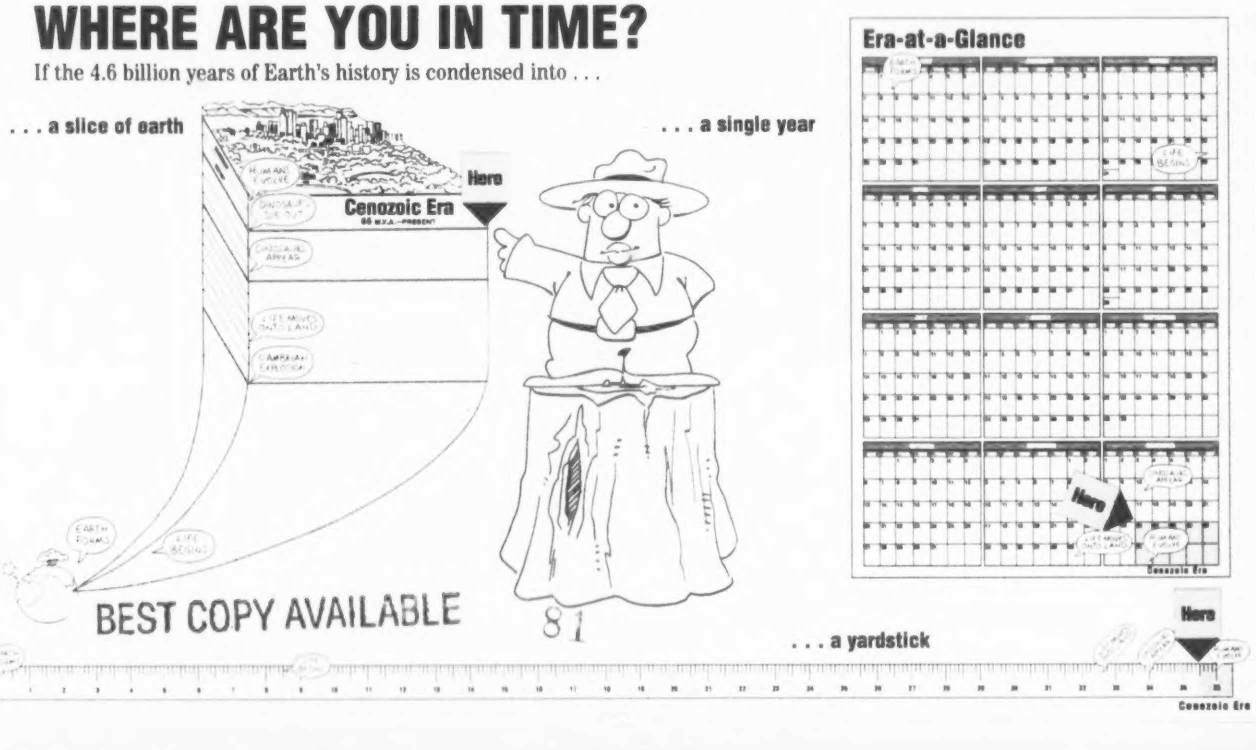
The Rocky Mountains began to rise about 65 million years ago, and continued to do so for the next 20 million years.

Grasses appeared for the first time. Grasslands began to expand as forests diminished.

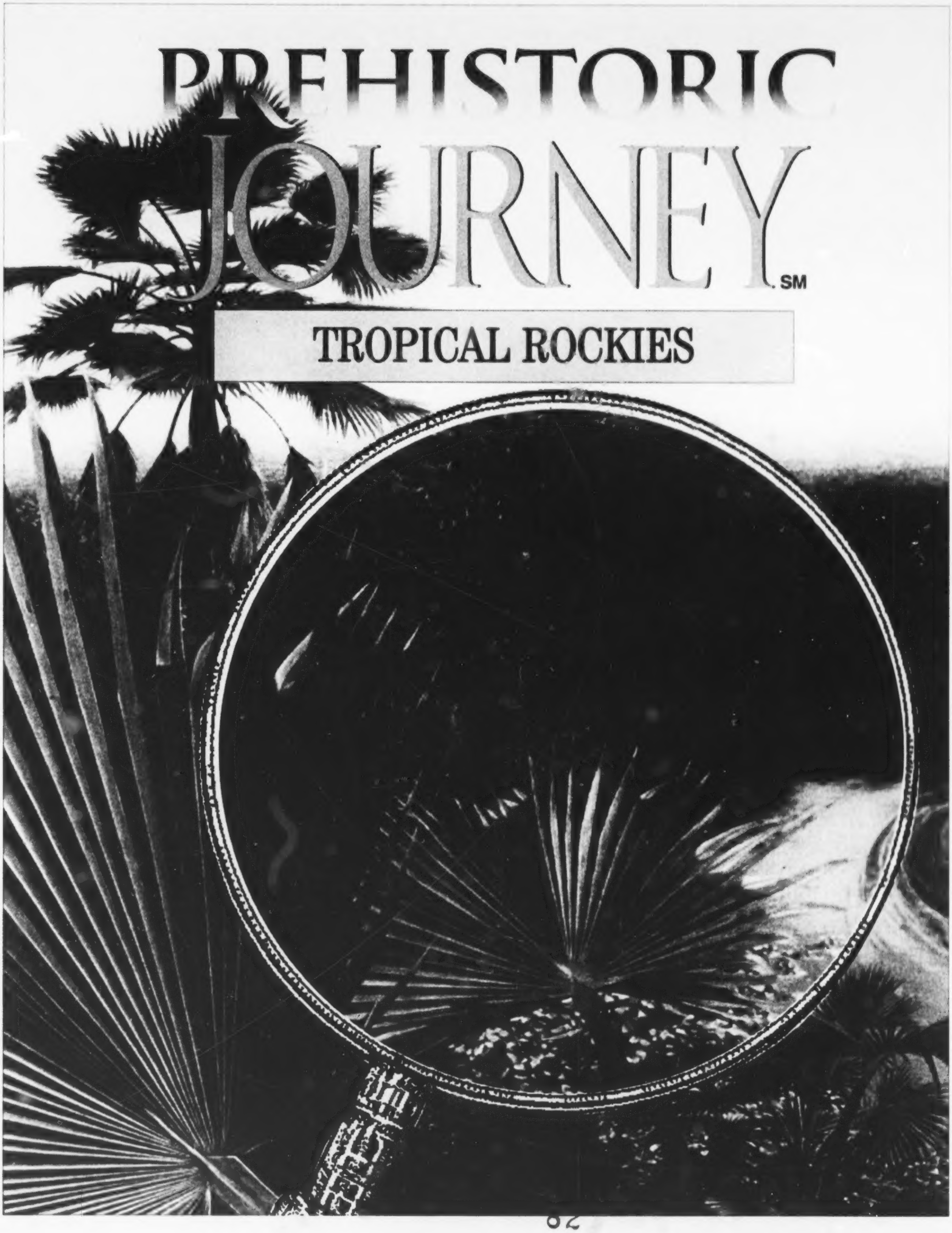
The human family evolved—more than 60 million years after the last dinosaurs died out.

WHERE ARE YOU IN TIME?

If the 4.6 billion years of Earth's history is condensed into . . .


. . . a slice of earth
. . . a single year
Era-at-a-Glance
Here
Cenozoic Era
65 M.Y.A.–PRESENT
HUMANS EVOLVE
DINOSAURS DIE OUT
DINOSAURS APPEAR
LIFE MOVES ONTO LAND
CAMBRIAN EXPLOSION
EARTH FORMS
LIFE BEGINS
. . . a yardstick
Cenozoic Era

BEST COPY AVAILABLE


PREHISTORIC
JOURNEY SM
TROPICAL ROCKIES

Around the World in 4.6 Billion Years:

A VIRTUAL *PREHISTORIC JOURNEY*

EPISODE VI:
The Reigning of the Shrew

Mmmm. That was a great night's sleep. I feel refreshed and ready to get out of this hole . . . {thud} . . . Hey! I thought I went to sleep in a hole—how did I end up lying here on the ground?

You were the size of a shrew when you went to sleep. But that was about 10 million years ago, and some mammals have grown larger since then. You no longer fit in that hole.

Oh no! Then I'm in b-b-b-big trouble. Out here in the open I'm just a t-t-tasty pterosaur ptreat waiting to happen!

You can stop shaking. The flying reptiles have retreated for good. They are gone.

Oh. Well I could still become a dinosaur's dinner.

Nope. No dinosaurs left. And if you were in the ocean, you could not become a mosasaur meal. The giant swimming reptiles are gone too.

Wow. What happened?

If I had the answer to that little riddle, I would be talking to Bryant Gumbel this morning instead of continuing with you on this virtual reality trip through time.

So there's nothing left to be scared of. Great. I can do whatever I want and . . . oh no! . . . There's a dinosaur coming this way—I knew you were setting me up for something.

Calm down. That is not a dinosaur. It is just a big bird—see, it has feathers.

Oh, you're right. Hey, and I have sharp teeth now! No big bird's going to scare me. Come on, I can take you. What are you–chicken? Baaaahhhhk, bahk, bahk, bahk . . .

Big mistake. I don't think it took kindly to you insulting its family heritage. The giant *Diatryma* may be related to chickens and . . .

. . . it's coming this way, it's screeching at the top of its lungs, and it looks hungry!

Run along that river, maybe the *Diatryma* is just protecting its chicks and will leave you alone.

Okay. Good idea . . . or not. The river is full of little crocodiles.

So what? You have sharp teeth, too—you are a carnivore.

You mean like a dog.

Well, even though you do look somewhat like a large dog, you are really a mesonychid. Mesonychids hunted along waterways during the Paleocene and Eocene epochs, the first two Epochs of the Tertiary Period, the time period directly after the dinosaurs went extinct.

It's still coming.

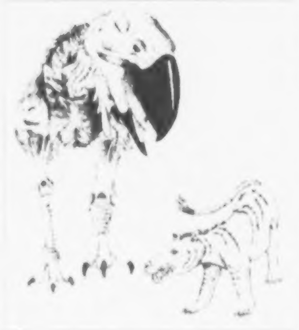
I guess it really is hungry.

Well, I'm not about to become a chicken dinner.

You cannot run forever.

Watch me . . .

Wow, you have gone a long way.



I think I went too far—I've run right into an ocean.

Well, at least the *Diatryma* is no longer in sight.

Yeah, but neither are my hind legs.

Sure they are, except now they are just tiny, useless appendages dangling from your giant body—your front legs, however, have turned into some very useful flippers.

How did that happen?

Through millions of years and many generations, mesonychids have evolved into the first whales.

So how do I get back out of the water?

You do not. Whales and their relatives have remained in the water over time. They have some of the largest brains of any animals around.

Well my big brain says it's not such a great idea to just swim around here waiting for a harpoon to hit me.

That could not happen for millions of years. The ancestors of humans are small primates living in the treetops of tropical rainforests right now. They are only just beginning to evolve the rotating shoulder joint and opposable thumb that will allow them to grasp and hurl harpoons and other such weapons in the future.

Well, I guess even if I could go back on land, that big Diatryma *would be there waiting for me.*

Actually, time has managed to remove *Diatryma* from the landscape, even without the help of hunting humans.

So the land must be a really great place to be right now. The dinosaurs are gone, and the humans aren't there yet. Couldn't I please take a look?

Well, all right. I will reset the program to start in Nebraska, 20 million years ago.

Thanks . . . I thought you said it was a tropical rainforest back on land. Instead of being up in the treetops where I can see everything, I'm eye-high in dry grass. It's hard to see anything through this.

The land was covered with tropical rainforests 50 million years ago, but since then, the landscape has been opening up. Herding and running animals like horses, rhinos, and camels have evolved. Look. There is a group of small camels now, running through the grass.

Camels in Nebraska? What are they running from? What's that noise like dry grass crunching under the foot of something huge?

They are running from a *Dino* . . .

Dino? There aren't any more dinos—all the huge, horrible dinos are extinct—aren't they?

All of the huge, horrible dino*saurs* , which means "terrible lizard," are extinct.

Oh, so, you could use "dino" in a name to mean terrible-something-else. But what else could be so terrible?

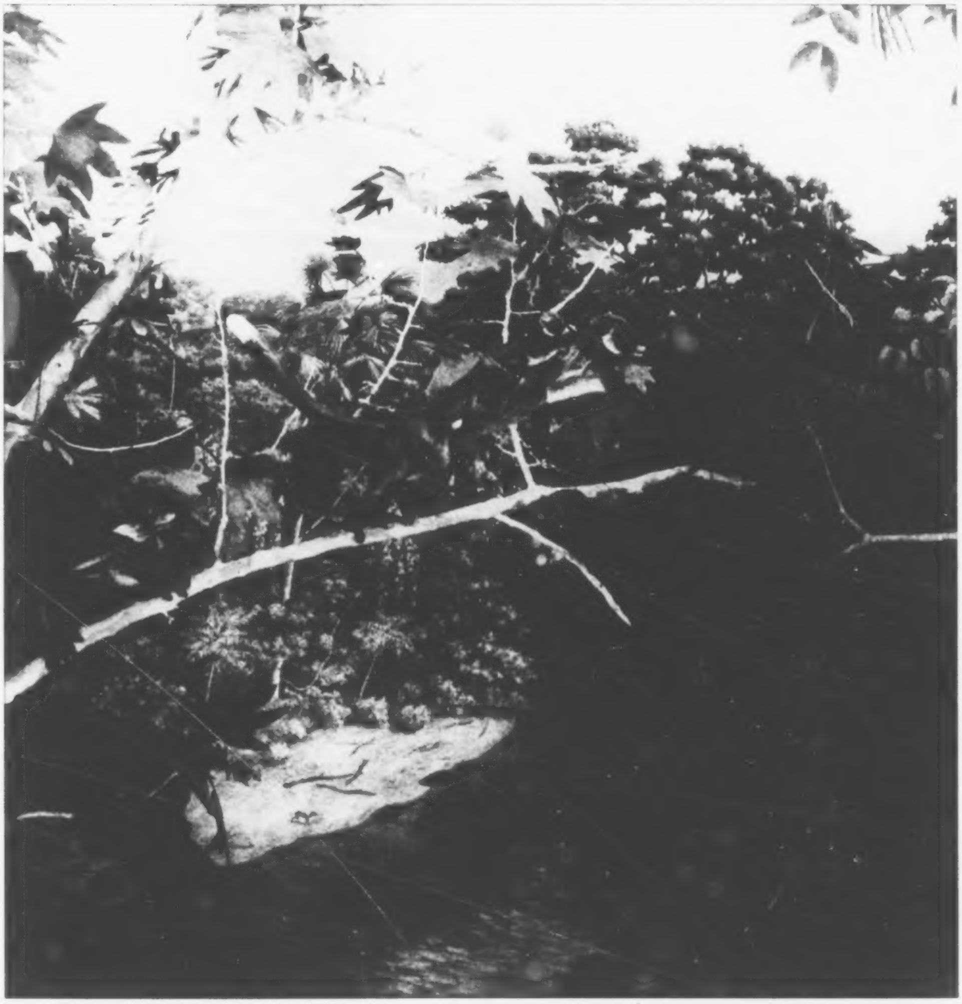
Turn around.

EPISODE VI: Through the Looking Grass

Rebecca Smith, Earth Sciences Educator

®Reprinted from ***Museum Quarterly*** 1994 Fall Issue

RAINFOREST TREETOP DIORAMA



TROPICAL ROCKIES

Rainforest Treetop

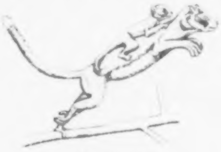
50 million years ago

NEW KINDS OF MAMMALS CALLED PRIMATES LIVE IN THE TREES of this warm Wyoming rainforest. There is plenty of food and shelter in the tree canopy, which the primates share with insects, birds, and snakes.

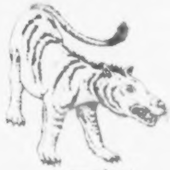
It has been 15 million years since the the last dinosaurs roamed the Cretaceous Creekbed.

EARLY PRIMATES

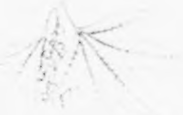
Lost Cabin, Wyoming
Early Eocene Epoch, 50 million years ago



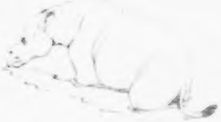
early primate
Northarctus venticolus



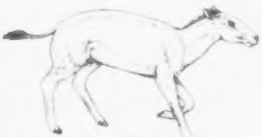
creodont
Prototomus vulpeculus



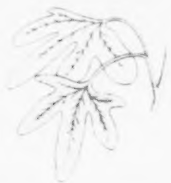
extinct sycamore tree
Macginitiea gracilis



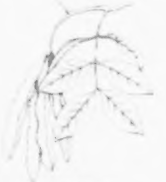
hippo-like mammal
Coryphodon sp.



dawn horse
Hyracotherium vasacciense



tree-climbing fern vine
Lygodium kaulfussi



pea-pod tree
Unknown at present

6. *TROPICAL ROCKIES* EVIDENCE AREA MAP

Once the dinosaurs were gone, mammals—including primates—came into their own. Colorado and the Rocky Mountain region were once tropical and forested.

VIEW the video, *Today's Rocks Are Yesterday's Sediments*
Paleontologists are detectives who use many clues to determine what ancient environments were like.

New technologies such as satellite imagery and computers help in finding fossils and reconstructing the past. Events of the past, such as global climate changes, can be used to help understand the present.

Evidence of a Rainforest Treetop

FIND OUT how we know that there was once a tropical forest where dry Wyoming hills are today.

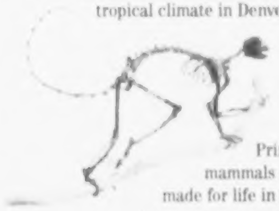
1 **THE RISE OF MAMMALS**
SEE skeletons of early mammals that lived after the Time of the Dinosaurs.

SEE plant fossils from Denver International Airport that show the tropical climate in Denver's past.

Life After Dinosaurs

New players

Rainforest Treetop Diorama



Primates are mammals that were made for life in the trees.

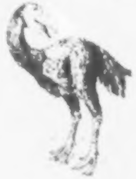
2

Legacy of Life in the Trees

Look familiar?

The Strange World of the Eocene
Some Eocene species were very strange. Such as the **bizarre-looking *Uintatheres***, which died out around 45 million years ago.

Terror Bird
The giant, flightless *Diatryma* was a vicious predator.



Try it!

DO what a primate can do! Primates can reach over their heads and hold onto things tightly.

Tropical Rockies

North America's climate was warm and wet during the Eocene, with abundant tropical vegetation.

Many fish and plant fossils were preserved in ancient lakes. Alligators, turtles, palm trees, and other tropical species lived here.

Be a fossil detective

Rocky Mountain Reptiles

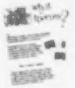
45 to 50 million years ago, the Rocky Mountain region had thriving populations of crocodiles and turtles.

Fossil Palm

The presence of palms is one way paleontologists know that the climate used to be much warmer.

Modern Mammal Ancestors

A great diversification of mammals began a mere 15 million years after the dinosaurs died out. **4**

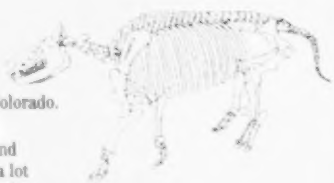


What Is a Species? **3**

Rhinos in North America?

How many rhinos?

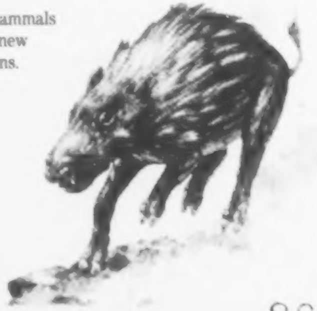
This *Trigonias* rhinoceros skeleton and bone bed were found in Weld County, Colorado.



The number and kinds of bones found together in fossil beds can tell you a lot about the animals when they were alive.

Big, Fast, and Social

As the climate cooled, some mammals became bigger and developed new social behaviors and adaptations. New predators evolved along with them.



Rocky Mountain Redwood Forests

Fossils from Florissant Fossil Beds National Monument give a picture of Colorado 35 million years ago.

1 ☞ MAMMALIAN ASCENDANCY

The mammals' rise is phenomenal. Within only a few million years of the dinosaurs' decline they achieved a richness in general that is similar to what exists today.

by Richard Stucky
Curator of Paleontology

In a geological instant the dinosaurs were gone, extinct at 65 million years ago. Most scientists now ascribe to the theory that they died via the cataclysmic impact of an asteroid, but whatever caused the extinction of the dinosaurs, the result is clear—there was an ecological revolution among the animals that lived on land. Small reptiles, birds, and especially mammals began to dominate the landscape almost immediately following the event. They still do so today.

Our best fossil record of this change in fauna comes from the mammals. They are very well studied and are the most commonly preserved fossils of terrestrial animals after the extinction. Fossil birds are rare and although reptile fossils are sometimes common, they are poorly studied compared to those of the mammals.

In biological parlance this rise in populations is termed an "adaptive radiation," which describes the scene as one of ecological adaptation and diversification. The adaptive radiation of the mammals is unprecedented in Earth history.

The mammals first appeared 220 million years ago, only about 5 million years after the first dinosaurs did. For 155 million years the mammals lived underfoot of the dinosaurs. Shrew-like and mouse-like in habits and size, these early mammals consisted of no more than two dozen species in any ecological community. They primarily fed on insects and seeds, but a few may have eaten leaves or the debris in the muck of the forest floor. All were generalists that would feed on almost anything they came across, especially if it had a high energy content. Some of these first mammals probably laid eggs, as do today's living monotreme mammals—the spiny echidna and duckbilled platypus of Australia. Mammals that bear live young—placentals and marsupials—probably did not appear until 90 to 100 million years ago. Neither the egg-laying, placental, nor marsupial mammals invested much care in the young, and it is likely that most lived for only a few years. But like today's small mammals they were able to reproduce quickly and expand their numbers. They relied on instinct more than intellect for the discovery of food and places to sleep or places to hide from the carnivorous dinosaurs that towered overhead.

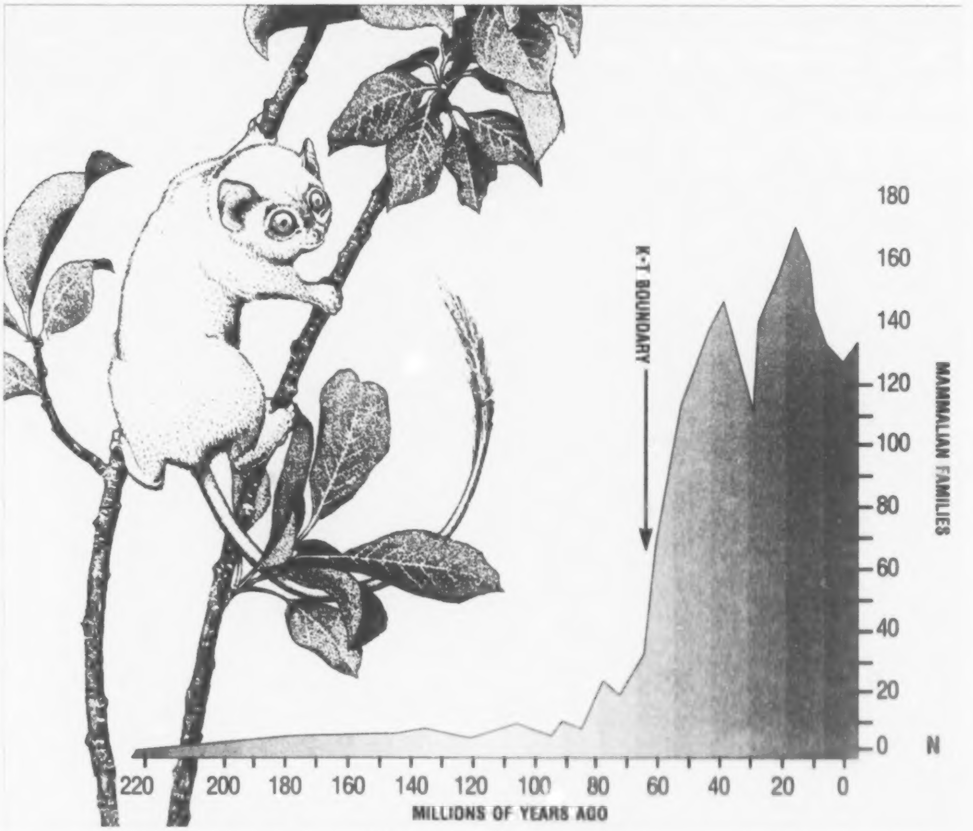
All in all, the ancient ancestors of modern mammals were not very sophisticated. But they did have special features that may have given them an advantage when opportunity knocked. As mammals evolved from reptile-like ancestors, they developed a sensitive hearing mechanism, perhaps to detect predators. Bones that had been part of the reptile jaw became the anvil, stirrup, and malleus—the tiny bones—of the ear. They developed hair and special sets of teeth that could handle almost any kind of food, be it an insect, seed, fruit, or bit of leaf. It is quite likely that the evolution of mammals had been held back by the dinosaurs—with their demise, the mammals seized the day to recast the ecological play for their own theater.

The latest Cretaceous dinosaurs were similar to one another in many ways, especially in their ecological specialization and size—most weighed as much as several tons. *Triceratops* and its relatives, and the duckbilled dinosaurs, were the primary plant-eating creatures on land who had specialized teeth. The tooth batteries in *Triceratops* and the duckbills were much like a vegetable or cheese grater with multiple ridges for shearing leaves into small bits. Quarry sites preserve hundreds of skeletons of some of the large ceratopsian and duckbilled creatures, suggesting that they traveled in herds. If this is the case, they would have laid waste and ecological devastation as they cleared paths through the forests.

Meat-eating dinosaurs were quick and relied on keen vision to identify their next potential meal. While an adult *Tyrannosaurus rex* hunted other dinosaurs, youthful *T. rex* and some of the smaller carnivorous dinosaurs no doubt preyed on small mammals. Dinosaur predatory habits were probably the reason mammals stayed small. While most plant-eating dinosaurs were big enough to hold their own against the carnivorous dinosaurs, the small mammals sought refuge by scampering into the secretive reaches of brush and foliage where they blended into the surrounding scenery.

With the dinosaur herbivores extinct, the forests probably became more dense because no creatures were around to feed continuously on the foliage. Pathways grew over and even at midday the forest floor remained dark. This is suggested by some plants, whose seeds actually became much larger after the extinction of the dinosaurs. Larger seeds provide the moisture and nourishment to sustain life until the plant has grown enough to capture the energy from the sun that is necessary for photosynthesis. With less light reaching the forest floor, plants needed larger seeds to survive longer in the dark.

Reprinted from *Museum Quarterly* / Spring 1995



CAN YOU SAY "ADAPTIVE RADIATION"? THIS GRAPH CHARTS THE RISE IN MAMMALIAN DIVERSITY. NOTE THE EXPLOSION AFTER THE K-T BOUNDARY. INSET, SHOSHONIUS WAS AN EARLY PRIMATE OF THE EOCENE THAT INHABITED COLORADO 50 MILLION YEARS AGO.

Coincidentally, larger seeds also presented a new food opportunity for the mammals.

By 50 million years ago, practically all of the modern groups of mammals were in existence, overlapping with many primitive groups that were destined for the same fate as the dinosaurs. Extinction is common; more than 90 percent of the mammal genera that have ever lived in North America have now gone extinct.

Mammals did not simply move into dinosaur niches. Building upon their small size and a proclivity to eat a diverse diet, they gradually specialized into carnivores and herbivores. At first, the mammals who survived the dinosaur extinction were no different than their parents before—small, secretive, and generalized. The number of plant-eating mammals began to increase soon after the dinosaur extinction, but with little specialization. A million years after the dinosaurs were gone, their teeth were still generalized, suggesting that while some mammals may have specialized more on eating leaves, they were still quite capable of feeding on insects, seeds, or fruits. Mammals were still tied to scampering on the forest floor, and were no larger than a cocker spaniel.

But by about 3 million years after the extinction, some of the mammals took to the treetops; mammals that are ecologically equivalent to primates and flying squirrels became abundant. They developed long, prying incisors or front teeth that projected forward for poking into insect burrows in trees, into bark to release sweet gum, or gnawed away at the hard outer shells of nuts. Leaf-eating mammals began to show changes, although their teeth looked more like meat tenderizers than vegetable graters during the early history of the mammals' adaptive radiation. Carnivorous mammals appeared, but unlike the dinosaurs who had knifelike teeth for piercing or tearing into flesh, the mammal carnivores had scissor-like molars for slicing meat into tiny bits. Their sharp canine teeth were the only knifelike ones in the mammal's entire tooth row.

It would take from 5 to 15 million years after the extinction before the modern orders of mammals appeared. With the origin of such groups as the rodents, primates, bats, horses, rhinos, tapirs, and strange hippo- and antelope-like mammals, the mammalian communities began to take on a modern look. After the dinosaur extinction, mammals evolved in predominantly tropical habitats during a period of global warming. A trend toward global cooling took place beginning about 50 million years ago, and with it the emergence of open savanna habitats. Some mammals took the route of the dinosaurs and got larger, but never achieved the truly gigantic size of the sauropods. They did become highly specialized in their diets and as early as about 45 million years ago, we have evidence that at least some of the larger animals began to travel in herds. With the opening of habitats came swifter runners, and coincidentally animals with specialized teeth more like vegetable graters. In a sense, the mammals replaced the dinosaurs as the most visible land-dwelling vertebrates.

Only 10,000 years ago the clock was partly reset for the mammals. In North America and many other parts of the world, many of the large mammals went extinct—mastodons, saber-tooth cats, camels, giant beavers, and lemurs—as well as many lizards and birds. In the past 10,000 years humans and their domesticated animals—sheep, goats, cows, pigs, dogs, horses, and cats—have flourished.

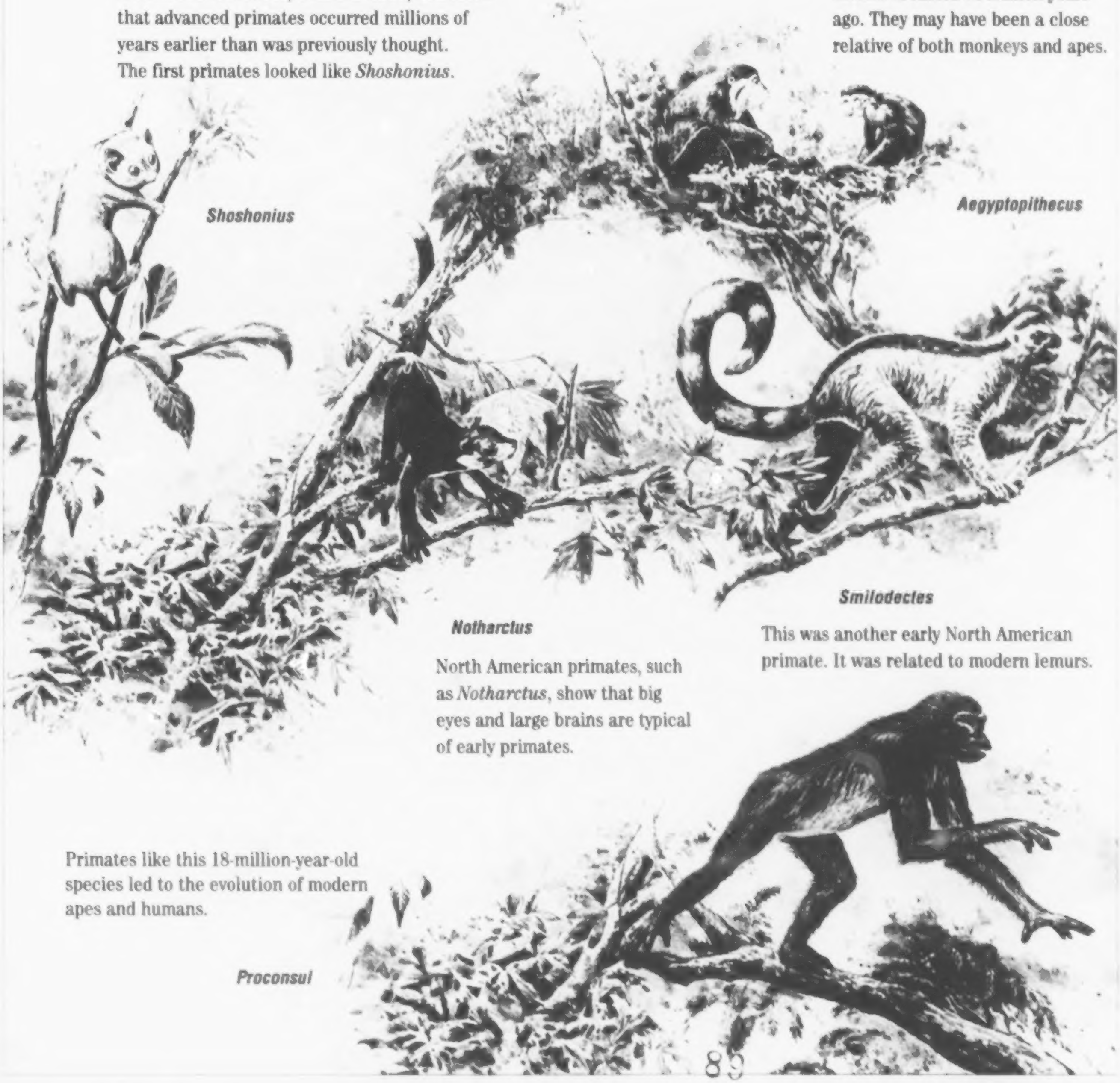
Both the human population and that of our domesticated animals continue to expand. Many of our native animals that made it through the last extinction are now in decline. Our habitats—metropolitan areas and fields of pasture and grain—are overtaking natural habitats. All of these changes are on a pace that is similar to the extinction of the dinosaurs. Perhaps we are on the cusp of a new evolutionary play. The players have now changed, and perhaps the future will be as dramatic as the change that occurred after the dinosaur extinction. Only time will tell.

2 Legacy of Life in the Trees

PRIMATES ARE TREE-DWELLERS THAT EVOLVED AS RAIN FORESTS expanded. They appeared around 60 million years ago in Africa, and soon migrated to Asia, Europe, and North and South America.

A skull of *Shoshonius*, found in 1985, indicated that advanced primates occurred millions of years earlier than was previously thought. The first primates looked like *Shoshonius*.

Cat-sized primates like *Aegyptopithecus* lived in the forests of Africa 36 million years ago. They may have been a close relative of both monkeys and apes.



Shoshonius

Aegyptopithecus

Smilodectes

This was another early North American primate. It was related to modern lemurs.

Notharctus

North American primates, such as *Notharctus*, show that big eyes and large brains are typical of early primates.

Primates like this 18-million-year-old species led to the evolution of modern apes and humans.

Proconsul

TROPICAL ROCKIES
Additional Background Information

3 WHAT IS A SPECIES?—FORMING NEW SPECIES

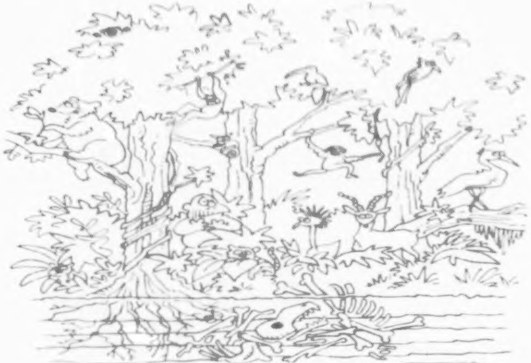
Occasionally a group of animals splits into two groups. Perhaps a newly formed river makes it impossible for the two groups to interact with each other. Or perhaps they find themselves on nearby islands after a natural land bridge has been destroyed. This process is called **geographic isolation**. Groups can also be **reproductively isolated**, due to some physiological or physical trait that prevents them from mating to produce fertile offspring—even if they live in the same place. In any event, the members of the two groups cannot mate with each other. When this situation occurs, each group evolves independently of the other. If the two groups have been geographically isolated, they will evolve in response to the particular conditions where each group lives. Perhaps the most famous example of this separation is the different types of finches that Charles Darwin found on nearby islands in the Galapagos. Each group of finches had beaks that were well suited for the type of food found on their own island. In fact, these finches were one of the early clues that helped Darwin formulate his theory of evolution.

If the groups remain out of contact for long enough, the groups may become so different that they would no longer be able to mate with the other group, even if they were able to come into contact. At this point, each of the two groups is considered to be different species. This process, known as **speciation**, has occurred countless times in the history of life on Earth.

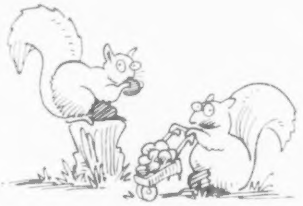
Natural selection alone does not produce speciation. Isolation, either geographic or reproductive, is required. Genetic drift can lead to speciation without natural selection.

WHY DID THE MAMMALS CHANGE?

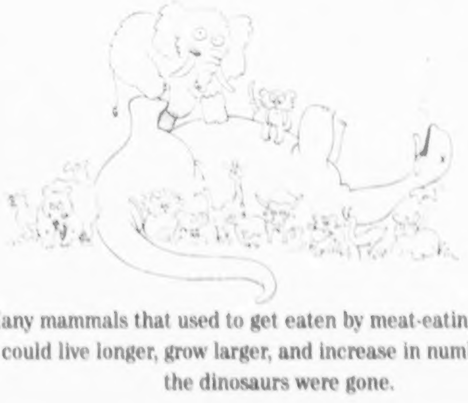
Many food sources and lots of space were left after the dinosaurs went extinct. New kinds of mammals moved right in to take advantage of them.



When there were no more big plant-eating dinosaurs to eat the vegetation, forests got more dense. Then there were new places for mammals to live on the forest floor and in the trees.

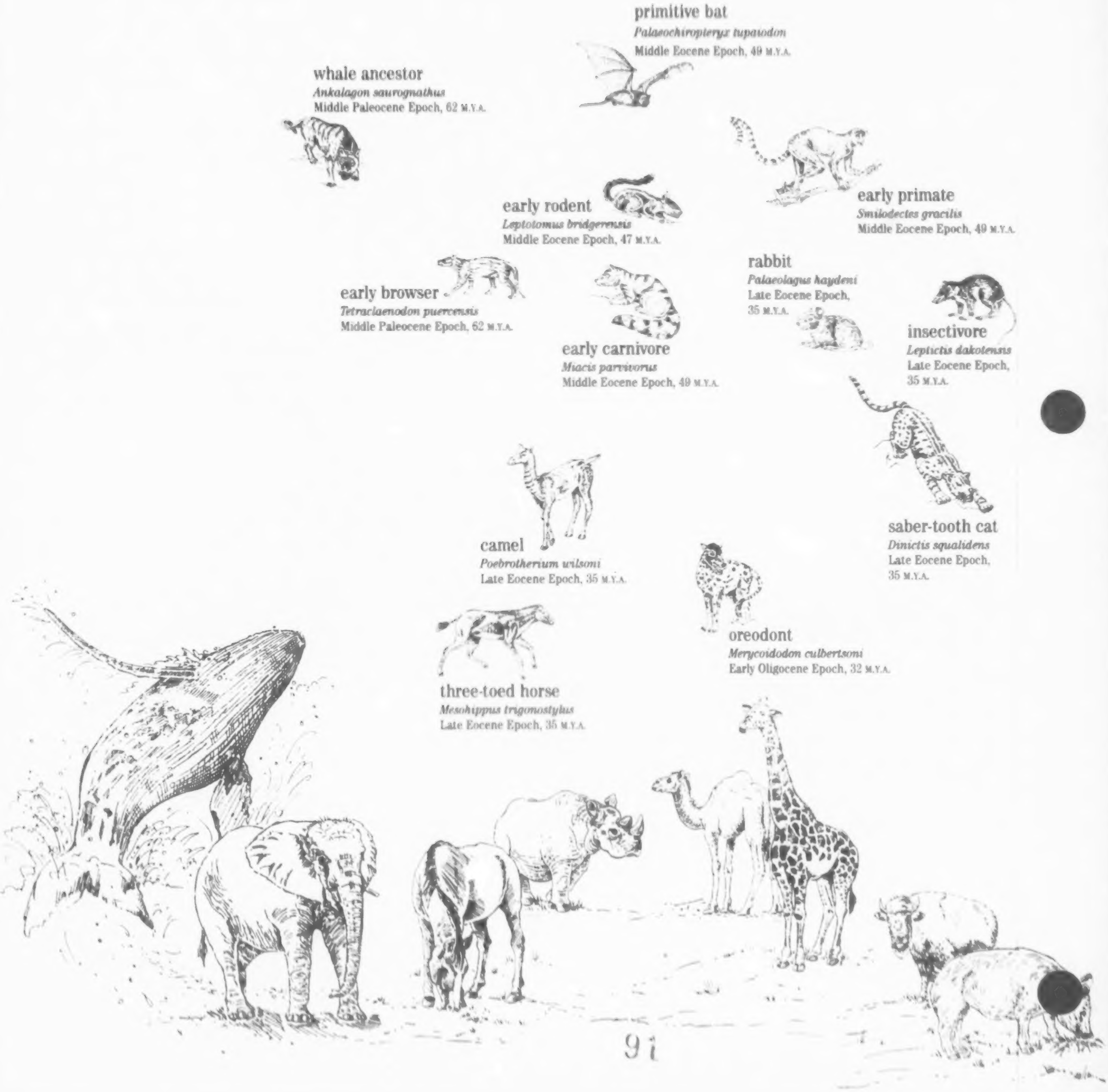


Plants in the dense forests have bigger seeds, so the plants can grow fast and tall. Big seeds provide lots of really good food for seed-eating mammals.

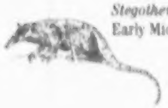


Many mammals that used to get eaten by meat-eating dinosaurs could live longer, grow larger, and increase in numbers once the dinosaurs were gone.

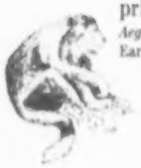
4 ☞ Ancestors of Modern Mammals


primitive bat
Palaeochiropteryx tupaiodon
Middle Eocene Epoch, 49 M.Y.A.
whale ancestor
Ankalagon saurognathus
Middle Paleocene Epoch, 62 M.Y.A.
early rodent
Leptotomus bridgerensis
Middle Eocene Epoch, 47 M.Y.A.
early primate
Smilodectes gracilis
Middle Eocene Epoch, 49 M.Y.A.
early browser
Tetraclaenodon puercensis
Middle Paleocene Epoch, 62 M.Y.A.
rabbit
Palaeolagus haydeni
Late Eocene Epoch,
35 M.Y.A.
insectivore
Leptictis dakotensis
Late Eocene Epoch,
35 M.Y.A.
early carnivore
Miacis parvivorus
Middle Eocene Epoch, 49 M.Y.A.
saber-tooth cat
Dinictis squalidens
Late Eocene Epoch,
35 M.Y.A.
camel
Poebrotherium wilsoni
Late Eocene Epoch, 35 M.Y.A.
oreodont
Merycoidodon culbertsoni
Early Oligocene Epoch, 32 M.Y.A.
three-toed horse
Mesohippus trigonostylus
Late Eocene Epoch, 35 M.Y.A.

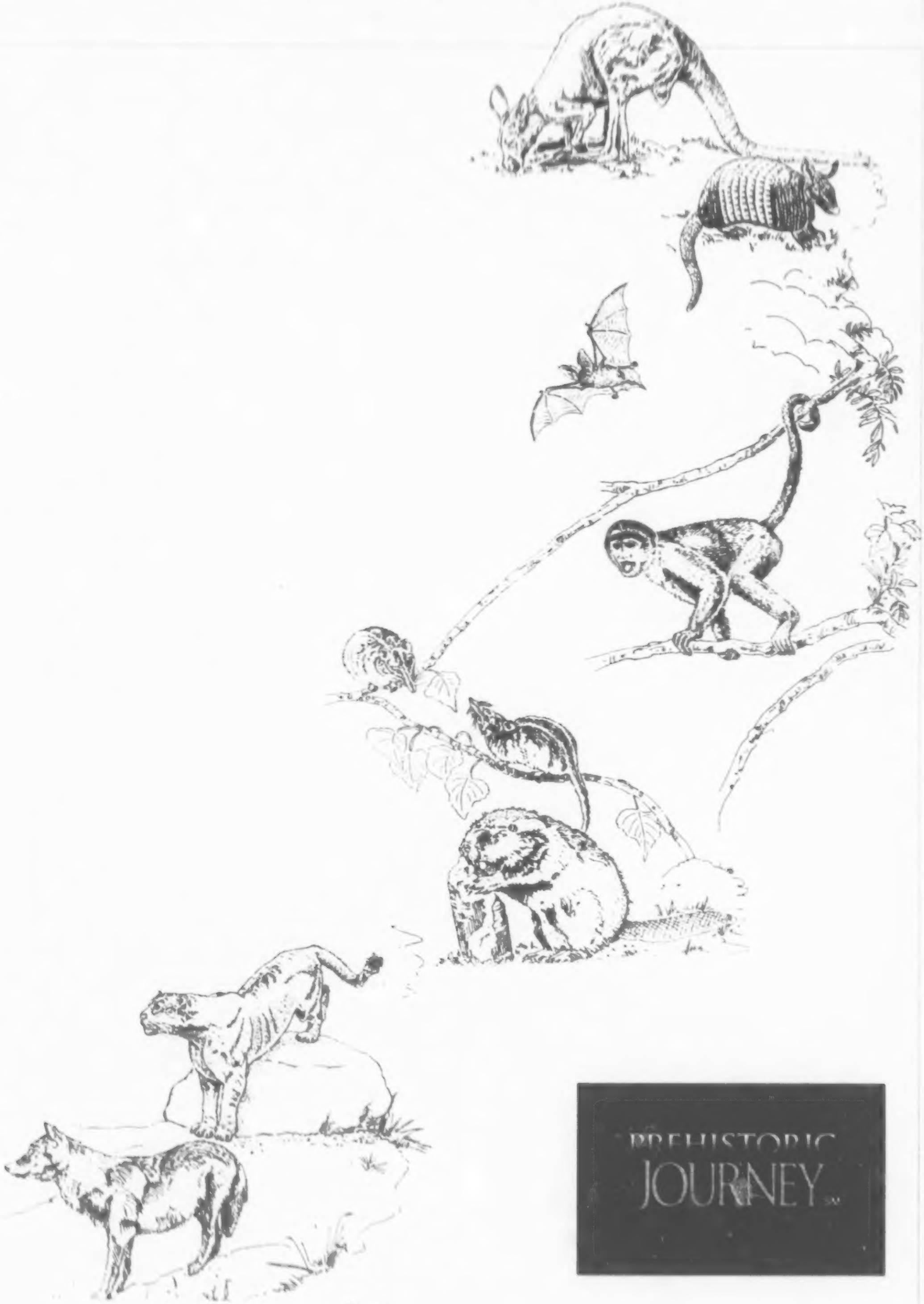
Most of the kinds of mammals we recognize today had begun to evolve by 50 million years ago.



armadillo
Stegotherium tesselatum
Early Miocene Epoch, 22 M.Y.A.



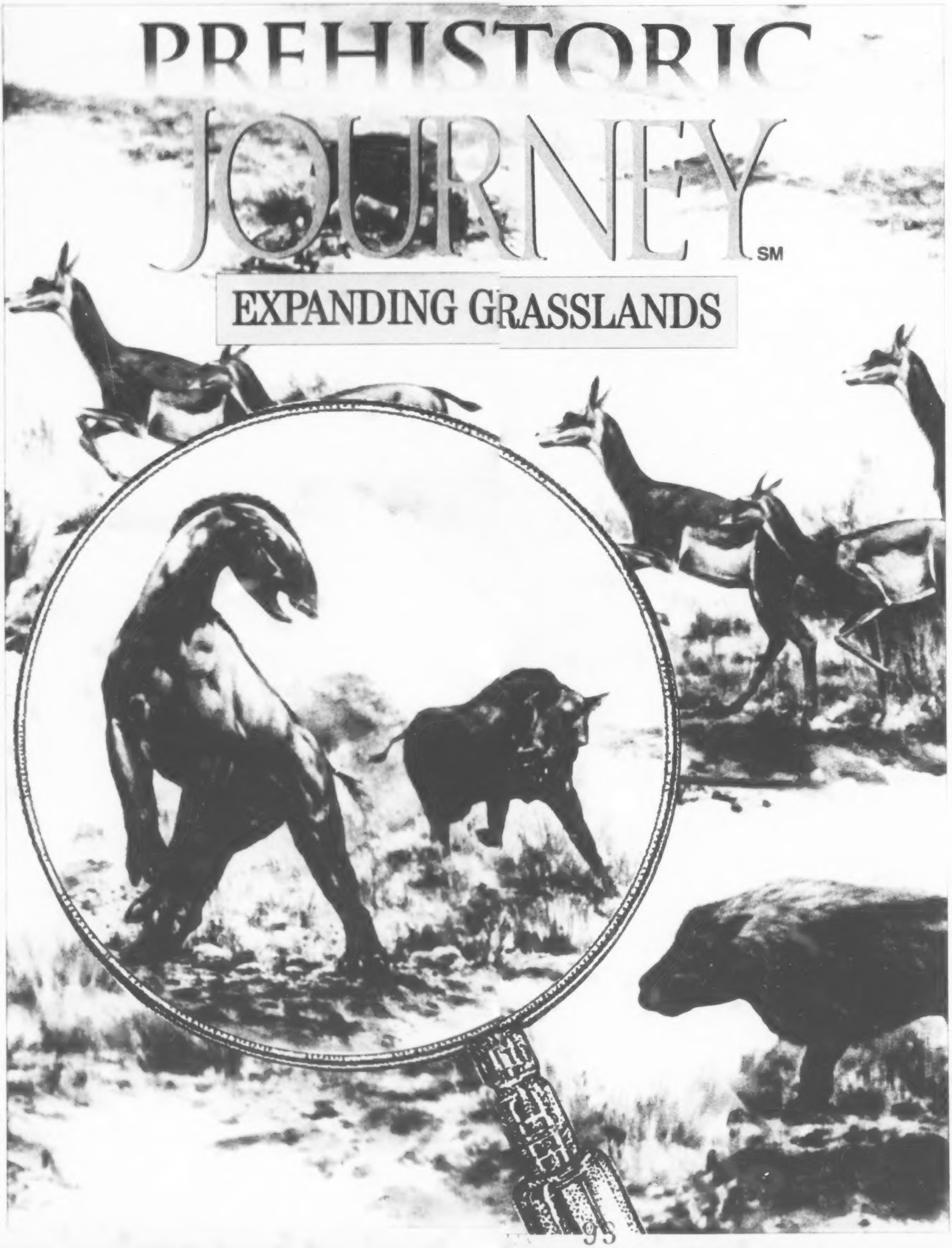
primate
Aegyptopithecus zeuxis
Early Oligocene Epoch, 32 M.Y.A.



PREHISTORIC JOURNEY

PREHISTORIC JOURNEY℠

EXPANDING GRASSLANDS



Around the World in 4.6 Billion Years:

A VIRTUAL *PREHISTORIC JOURNEY*

EPISODE VII:

Through the Looking Grass

The program is currently allowing you to experience the world as *Archaeolagus*—an ancient rabbit.

A rabbit? There's some terrible dino-something behind me making loud crunching noises and I'm a soft little bunny rabbit? Great.

I would not worry about getting eaten, it is very unlikely that it will notice you. It is more likely that it will squash you on the way to those little camels.

I think you may be right. It's coming closer. It's . . . it's . . . it's . . . Ick! It's drooling all over me. Wow, its head is almost as big as a T. rex's. *What is it?*

It is a *Dinohyus*, an extinct relative of camels, pigs, and hippopotamuses, but really, there is not time to . . .

Ow! Uh-oh, it knocked me into a ho-oo-wo-oo-wo-oo-wo-oo-wheeee!!!!!! What a ride! Falling down this hole is like riding a corkscrew roller coaster straight toward the center of the Earth! [THUD]. Hey, it's still dark in here and I've hit the end of the tunnel. But at least it was a soft landing—I guess someone dropped their beaver-skin hat in here—hey, that hat just bit me!

That is because you are trespassing in its burrow.

And what, pray tell, is it?

The ancient land beaver, *Paleocastor.*

I didn't know beavers made crazy tunnels like this.

Neither did scientists who first found these burrows. They named them *Daemonelix*, the Devil's corkscrew, and then later found the beavers at the bottoms of the burrows.

That's all very interesting, but how am I supposed to get out of here?

Well, since you are late for a very important date, I will . . .

What important date?

3.5 million years ago.

What's so important about it?

Climb out of that silly hole and find out.

Okay. I'm near the surface—hey, the hole changed—I hope I've changed too—into something other than that little defenseless Archaeolagus.

You have. Now you are a little defenseless *Serengetilagus!*

Serengeti . . . sounds like I must be in Africa. And it sounds like someone's coming my way . . . oh! Not agaaaaaaaaaaain.

Oh, calm down. You should consider yourself privileged to have been stepped on by your great, great, great grandmother 3.5 million years removed as she stepped down from that tree.

My great grandmother rabbit?

No silly, you are a human. Are you starting to lose touch with the difference between virtual reality and actual reality?

No, but I still have no idea what you're talking about.

That two-legged creature that just stepped on you—she's better known as Lucy. Her scientific name is *Australopithecus*, and she is an early hominid, or member of the human family.

That was Lucy? Wow—she's so small. It must be dangerous for her with all the lions, leopards, and hyenas that must live around here.

Well, australopithecines must have lived long enough to pass on their genes to the likes of you.

Speaking of me, a little rabbit isn't too safe out here with all of those cats either. It was exciting to see the beginning of the human family, but as long as I'm a virtual bunny, I'd like to go somewhere a little less carnivorous than the African plains—like the good old USA.

Alright then. Back to America you go.

Great. Hey, did it get cooler?

Yes. This is the Pleistocene Epoch, the time known as the Ice Age.

Wow, that pronghorn was in an awfully big hurry. Those Dinohyuses *aren't still around, are they?*

Rest assured they are quite extinct. That pronghorn was running from a . . .

A very big cat! That's a cheetah! We never left Africa, did we?

Of course we did. We are back in the good old not-yet-the-USA.

Then what is a cheetah doing here? It can't have escaped from a zoo—there aren't any zoos yet.

During the Pleistocene, lions, elephants, and cheetahs lived in North America. And so did walruses—in New Jersey.

Walruses in New Jersey? That's it—the time has come to end the program.

No, you cannot do that. There is still much more to learn.

Like what?

Well, with apologies to Lewis Carroll:

There is still time (the program said)
To talk of ancient things
Of trilobites and ammonites,
And *Tyrannosaurus* "kings,"
And dinosaurs evolving into
Birds with teeth and wings.

The time has come, this rabbit says,
To talk of time no more;
I miss my home and family,
And solid, hole-free floor,
And my short-eared human body—
Falling's made these long ears sore!

But wait a bit (the program cried)
We start now to arrive
In present time and present place—
Fall 1995,
Where in actual reality
The past has come alive!

Oh humans, come and walk with me
(A narrator did beseach)
3.5 billion years of life
Is now within your reach.
We'll start along this shallow sea.
Even then, life was a beach!

On your *Prehistoric Journey*
You will take a trail through time
Through the record of the ages,
Sea to land to sky you'll climb
For life's wondrous past, come try
  to grasp
The reason to the rhyme.

Oh what the heck, I'll go again
You've managed to convince me.
No better fun is to be had
While learning so intensely,
But the part that I like best of all
Is when the past invents me!

Rebecca Smith, Earth Sciences Educator

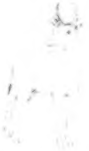
®Reprinted from ***Museum Quarterly***,
1995 Fall Issue

THE LANDSCAPE OPENS UP

Agate Springs, Nebraska
Early Miocene Epoch,
20 million years ago

raptor

hackberry trees
Celtis sp.



slingshot-horned antelope
Syndyoceras sp.

cottonwood tree
Populus sp.

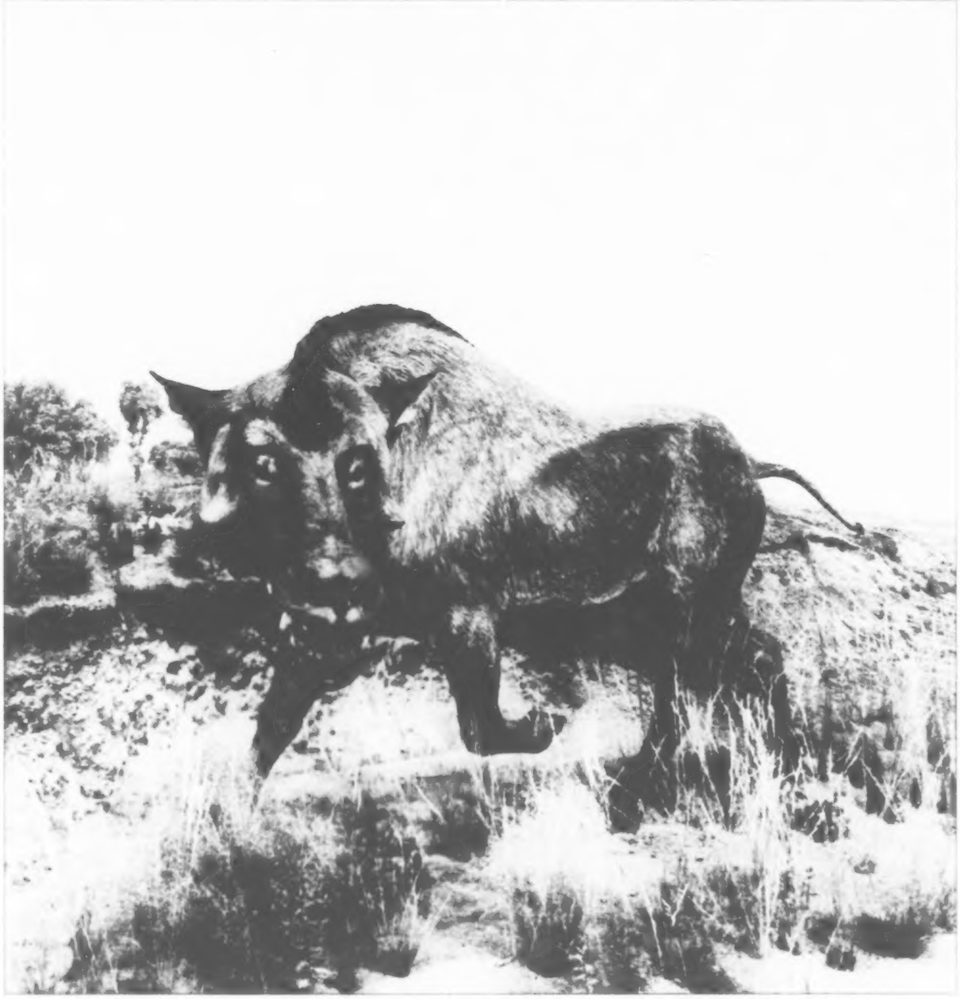
carnivorous pig-like entelodont
Dinohyus hollandi

Oregon grape
Mahonia sp.

three-toed horse
Parahippus sp.

rabbit
Archaeolagus sp.

NEBRASKA WOODLAND ENVIRORAMA



EXPANDING GRASSLANDS

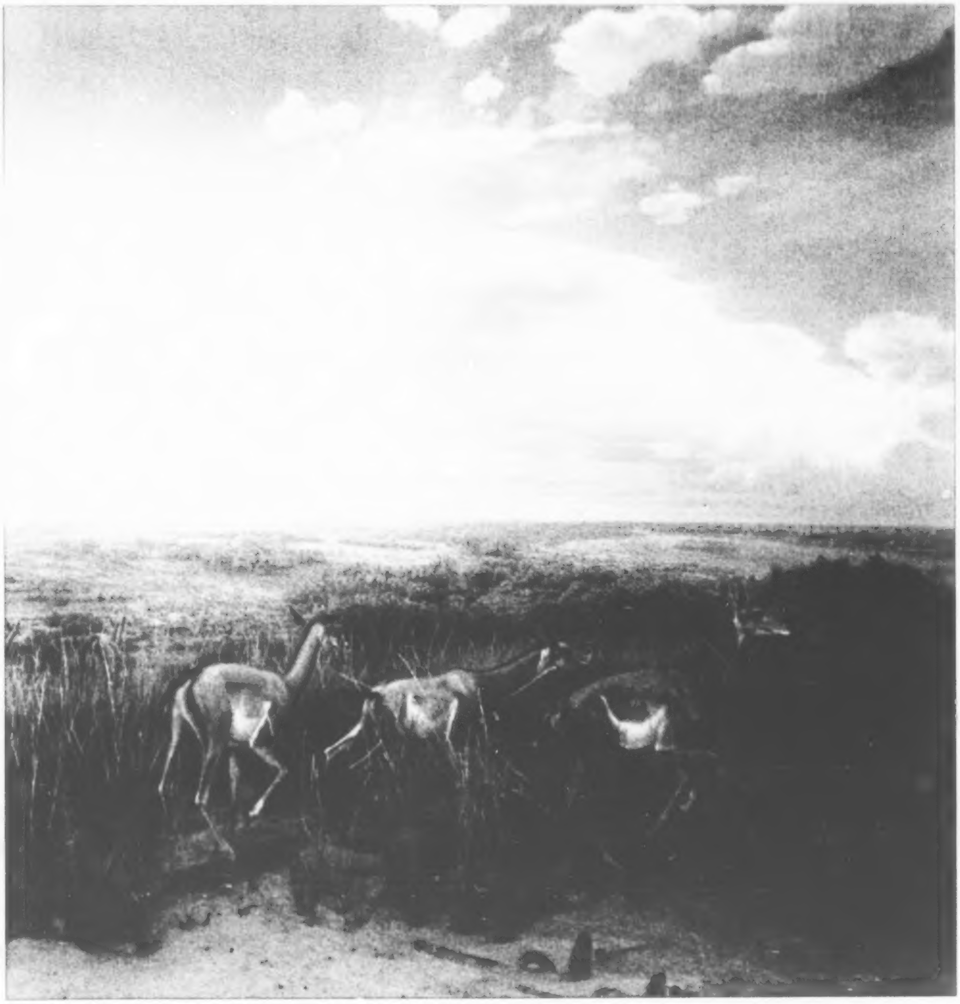
Nebraska Woodland

20 million years ago

A "BIG PIG" LOOMS MENACINGLY AS IT CATCHES SIGHT AND SCENT OF prey. A rabbit hides among the grasses on the right while three-toed horses graze calmly in the distance. Off to the left, a slingshot-horned antelope watches from a hilltop vantage point.

It has been 30 million years since early primates lived in the Rainforest Treetop.

NEBRASKA WOODLAND ENVIRORAMA



EXPANDING GRASSLANDS

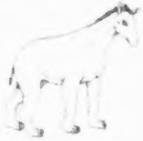
Nebraska Woodland

20 million years ago

A GROUP OF SMALL CAMELS TURNS TO FLEE FROM DANGER. IN THE distance, a herd of two-horned rhinos wanders near the river. Oreodonts graze nearby, and, far to the left, a chalicothere browses the patchy woods in search of food.

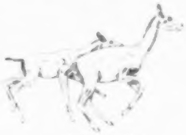
THE LANDSCAPE OPENS UP

Agate Springs, Nebraska
Early Miocene Epoch,
20 million years ago

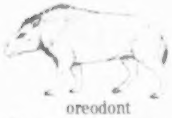


chalicothere
Moropus elatus

extinct grass
Berriochloa communis



gazelle camels
Stenomylus hitchcocki



oreodont
Merycochoerus magnus

two-horned rhinos
Menoceras arikarense

rice grass
Oryzopsis sp.

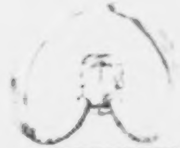
geese

ragweed
Ambrosia sp.

7. *EXPANDING GRASSLANDS* EVIDENCE AREA MAP

As the climate cooled and grasslands evolved, mammals—including primates—changed in response. Eventually, humans evolved.

Paleontology Lab



Mammoth Beasts

Touch a tooth

This giant skull is from *Mammuthus columbi*, which lived in Colorado and New Mexico 12,000 years ago.

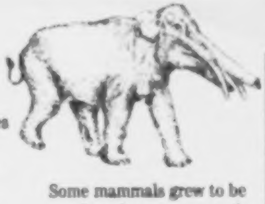
Life in the Cenozoic Seas

Ice Age!

During the Pleistocene Epoch there was a series of glaciations, with warmer periods in between.

The ancestors of today's whales lived on land 60 million years ago. Whales still had leftover legs 45 million years ago.

FIND OUT what other seagoing animals had landlubbing ancestors. **2**



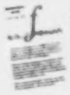
Some mammals grew to be nearly as large as some of the big dinosaurs.

Filling the Dinosaurs' Shoes

The Horse Tale

DID you know that horses evolved in North America?

Sherlock Bones and the Case of the Found Fossils
Taphonomy is the study of what happens to an animal from the time of its death to the discovery of its fossils.

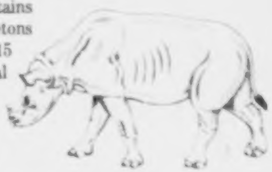


FIND out what clues taphonomists use to learn how ancient animals lived and died.

Bed of Bones

Rhino brain-teaser

This block of *Menoceras* bones contains the skeletons of 10 to 15 individual rhinos.



How do you think so many rhino bones ended up in one place?

Picture of the Past

Life changed a lot as the climate cooled, forests receded, and grasses evolved and flourished. The landscape began to look like a world you would recognize.

Million of years ago, world climates were cooling down from the warmth of the Eocene world.

Worldwide Climate Change

Cooling Down

Create a Climate

CREATE a climate by selecting different combinations of temperature, rainfall, and seasons.

Evidence of a Nebraska Woodland

Find out how we know that there were once patchy woods where Nebraska grasslands are today.

Giant Bison

Bison latifrons stood as tall as an elephant, and its horns spread as wide as a living room sofa! *Bison* living today are smaller and are commonly called American "buffalo."

A significant extinction took place in North America only 10,000 years ago, when many Ice Age species vanished.

Dating the Recent Past
Carbon 14 dating is a very effective way to determine the age of many things that are less than 50,000 years old.

The Human Family

Where Did We Come from?
Our understanding of human evolution is becoming clearer with each new discovery. Fossil evidence and molecular and DNA research demonstrate that humans are very closely related to the great apes: chimpanzees and gorillas.

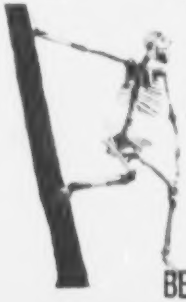
3

Hips and feet

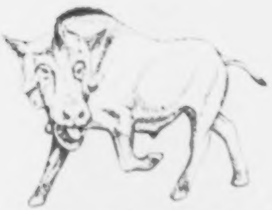
The Sleeping Tree

At the time grasslands were expanding worldwide, hominids began to evolve from earlier primates in Africa.

Modern humans, the only remaining hominids, evolved very recently—within the last 2 million years.



Australopithecus afarensis were the first members of the human—**or hominid**—family. The first australopithecines walked upright more than 4 million years ago.



Predators evolved along with prey. Predators' teeth specialized according to their lifestyles.

Dinohyus hollandi was a giant pig-like predator. **1**

Grazers evolved along with the grasslands. Teeth became more and more efficient for browsing and eating grasses.

Hoofed animals became faster and traveled in herds. Limbs became more and more specialized for running and living in open areas.

BEST COPY AVAILABLE

1 The Making of the TERMINATOR

What began as a humble ***jumble*** *of bones* ***in a Nebraska*** *field*

has been ***elevated*** *to one of the centerpieces* ***of the*** *Museum's* Prehistoric Journey *exhibition.*

Around the turn of the century, paleontologists discovered the rich country near the Niobrara River, a small tributary of the Mississippi River that cuts through the western Nebraska prairie. In an area now known as the Agate Springs Fossil Beds, some of the most sterling discoveries of fossil mammals in North America were unearthed. Beasts that lived some 20 million years ago were found—in great abundance—including previously unknown species that resembled hogs, hippopotamuses, and two-horned rhinos.

Once word got out about the area's incredible fossil bounty, field parties descended on Agate Springs like locusts on a field of wheat. Inevitable rivalries developed between these parties. One of the more interesting ones involved the discovery of a skeleton of *Dinohyus hollandi* (meaning "terrible hog"), a giant pig-like animal the size of a well-fed hippo in a buffalo body. A Yale University team found the tail end, Nebraska State University the head. The result? "The heads won and the skeleton is now in the University of Nebraska State Museum," relates Richard Stucky, the DMNH curator of paleontology.

Dinohyus, a solitary carnivore, was the last representative of a group of mammals that dominated the North American landscape from 37 million to 20 million years ago, from the late Eocene to early Miocene Epochs. At the time, the prehistoric "pig" from the entelodont family was the largest predator on the continent, with fossil evidence indicating its domain ranging from coast to coast. The environment around Agate Springs then consisted predominantly of hardwood forests with open spaces, having not yet evolved to today's prairie grasslands.

This dynamic area, specifically Agate Springs, has been recreated in the Museum's *Prehistoric Journey* permanent exhibition. State-of-the-art exhibitry techniques are evident in this Miocene woodland envirorama as, unlike the Museum's dioramas behind glass, visitors will actually walk through the middle of a simulated muddy waterhole in a park woodland during a thunderstorm from 20 million years ago.

RICK WICKER

The Making of the TERMINATOR PIG
(continued)

"It's the last major envirorama on the trail through time," Stucky says. "It more or less signifies the origin of the modern world with animals that are more familiar to all of us, like camels, horses, and rhinos." The voracious giant *Dinohyus hollandi* is in the envirorama.

The driving force behind the re-creation of *Dinohyus* was Denver Museum of Natural History sculptor-taxidermist Tom Shankster. Shankster, 38, worked at the Museum for a few years in the early 1980s before moving to Alaska and opening a taxidermy shop. He returned 10 years later, and has been working on the diorama hall renovation program and *Prehistoric Journey* ever since.

Once the prehistoric "pig's" original bones were carefully measured in the Nebraska museum, then laid out on paper to exact proportions, it was time to translate the two dimensions into a three-dimensional figure. Using hand tools, jigsaws, wire cutters, drills, and "our favorite tool in the department, a big rubber hammer," Shankster created the mock-up skeleton with plywood and wire, with a skull made out of carved foam. Volunteer Helen Bryant then helped apply the veritable mountain of clay to the hollow wood-and-wire figure.

Tom Shankster does a brush-up job on the furrowed snout of the prehistoric *Dinohyus*.

The cantankerousness of the *Dinohyus* comes predominantly from its size and its terrifying grimace. Apparently, the animal that was found at Agate Springs was an old animal with chipped teeth, and Shankster did an expert job of revealing the animal's evidently unkind disposition.

With Stucky giving direction about what scientists think the animal looked like, Shankster was given a good dose of artistic freedom to determine the beast's pose and expression. "Feedback from people coming to look helped," Shankster says. "At first people thought he looked a little bit too friendly, so we tried to make him look meaner."

The envirorama is set up so that the *Dinohyus* is on one side of the gallery, with the walkway for visitors cutting through the middle of the woodland scene. Visitors see a trio of ancient camels called *Stenomylus* first, then look back over their shoulders to see the menacing "Terminator Pig" coming up over a hill toward them and the camels.

"I like the positioning of *Dinohyus*," says Shankster. "Especially its turning and wheeling stance, and how it is a nasty, gnarly, cantankerous old pig. People seem to like it, and it makes me feel good that it seems to go over pretty well."

After finishing the clay sculpture of the 7-foot-tall beast, molds were made and a cast was made by laying up quarter-inch polyester resin fiberglass, which is the same material used to make some sailboats. After the cast of the pig was made, Shankster sanded it and touched up its seams. A gray coat of priming paint was applied to its entire body. At this stage, the beast was completely gray except for features around its head—teeth, tongue, and drool—ostensibly what gives "Terminator Pig" its name. "It looks vicious, it's drooling, and it's apt to kill everything in its path," says Rebecca Smith, exhibit educator. "It is very clearly a Terminator Pig."

Then there is the case of the accidental drool. As Shankster tells it, "There was fiberglass in his mouth, and a little fiberglass drool came running down the tongue. It looked pretty good, but it actually was just an accident. We'll probably put a little bit more in there now for effect."

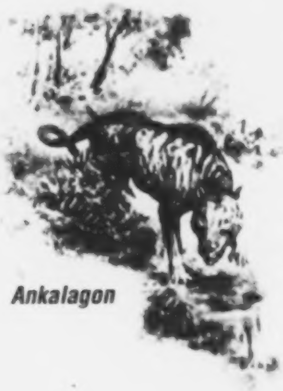
The final pieces that infuse the "pig" with life are the eyes. Shankster had a number of different animal eyes to choose from, among them an elephant's, but there were no *Dinohyus*-size pig eyes available. With input from Stucky, they settled on brown glass giraffe eyes that are similar to those of hogs and camels.

The pig was then painted in lifelike colors and placed in its present pose in the *Prehistoric Journey* envirorama. With its snarling mouth agape at the end of an elongate furrowed snout, teeth stained and chiseled, tongue salivating, and beady eyes fixed and focused across the main trail, *Dinohyus hollandi*—"Terminator Pig"—ought to look as compelling to visitors as it does to the three *Stenomylus* camels that are being ravenously considered for lunch by the *Dinohyus*. —Todd Runestad

2 LIFE IN THE CENOZOIC SEAS

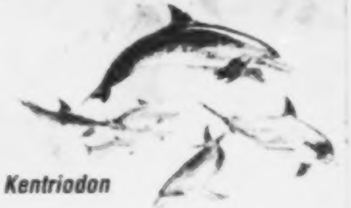
SOME MAMMALS RETURNED TO THE OCEAN AFTER many years of evolving on land. Eventually, they adapted completely to their new watery world.

Seas and oceans cover about 75 percent of Earth's surface, so a huge, rich habitat was ready and waiting for new inhabitants after the big marine reptiles went extinct.



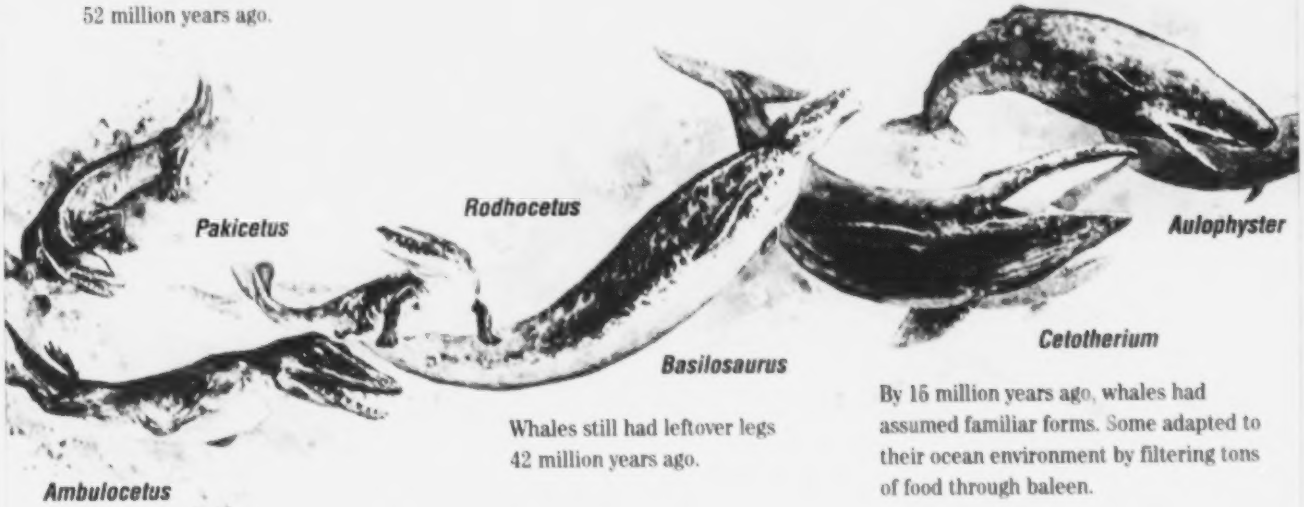
The ancestors of today's whales lived on land 62 million years ago.

Dolphins and other porpoises are small toothed whales. They became marine specialists by developing into superb, fast swimmers.



Remarkably, sperm whales—which have teeth instead of baleen—can dive as deep as a mile to find food.

This small whale with legs lived in the water 52 million years ago.



Whales still had leftover legs 42 million years ago.

By 15 million years ago, whales had assumed familiar forms. Some adapted to their ocean environment by filtering tons of food through baleen.

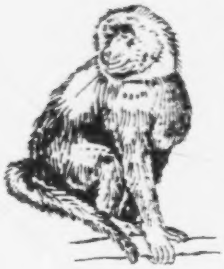
Fifty million years ago, whales like this one were propelling themselves through the water like otters–moving their legs up and down much like a modern whale's tail.

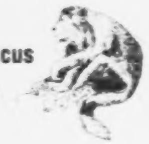
3 WHERE DID WE COME FROM?

DNA research and new fossil finds continue to add to our knowledge of our own origins long ago in Africa.

APES

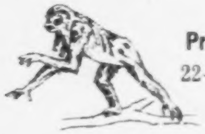
OLD WORLD MONKEYS



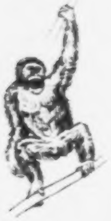


Aegyptopithecus
32 M.Y.A.

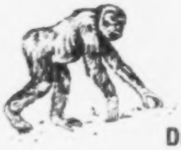
NEW WORLD MONKEYS



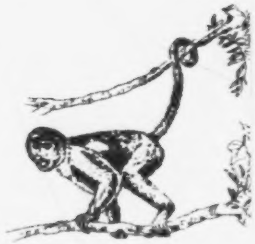
Proconsul
22–14 M.Y.A.

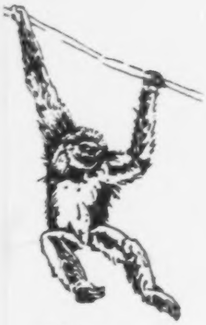


Sivapithecus
11–7 M.Y.A.

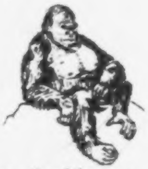


Dryopithecus
11–9 M.Y.A.





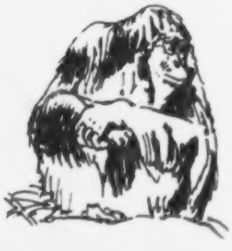
gibbons



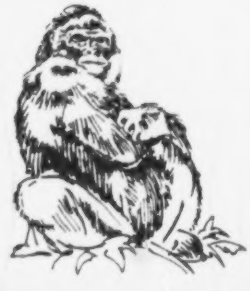
Gigantopithecus
8–1 M.Y.A.

DNA evidence shows that orangutans—Asian great apes—branched off about 12 million years ago. African apes evolved 6 to 8 million years ago, and the human family is about 4 million years old. There is a 97.6 percent DNA match between humans and orangutans, 98.6 percent with gorillas, and 98.8 percent between us and chimpanzees.

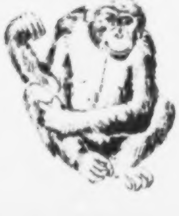
orangutans



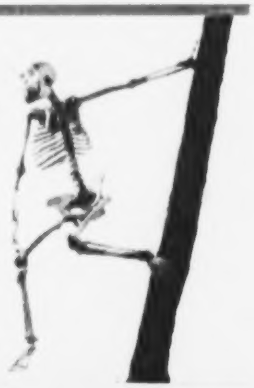
gorillas



chimpanzees



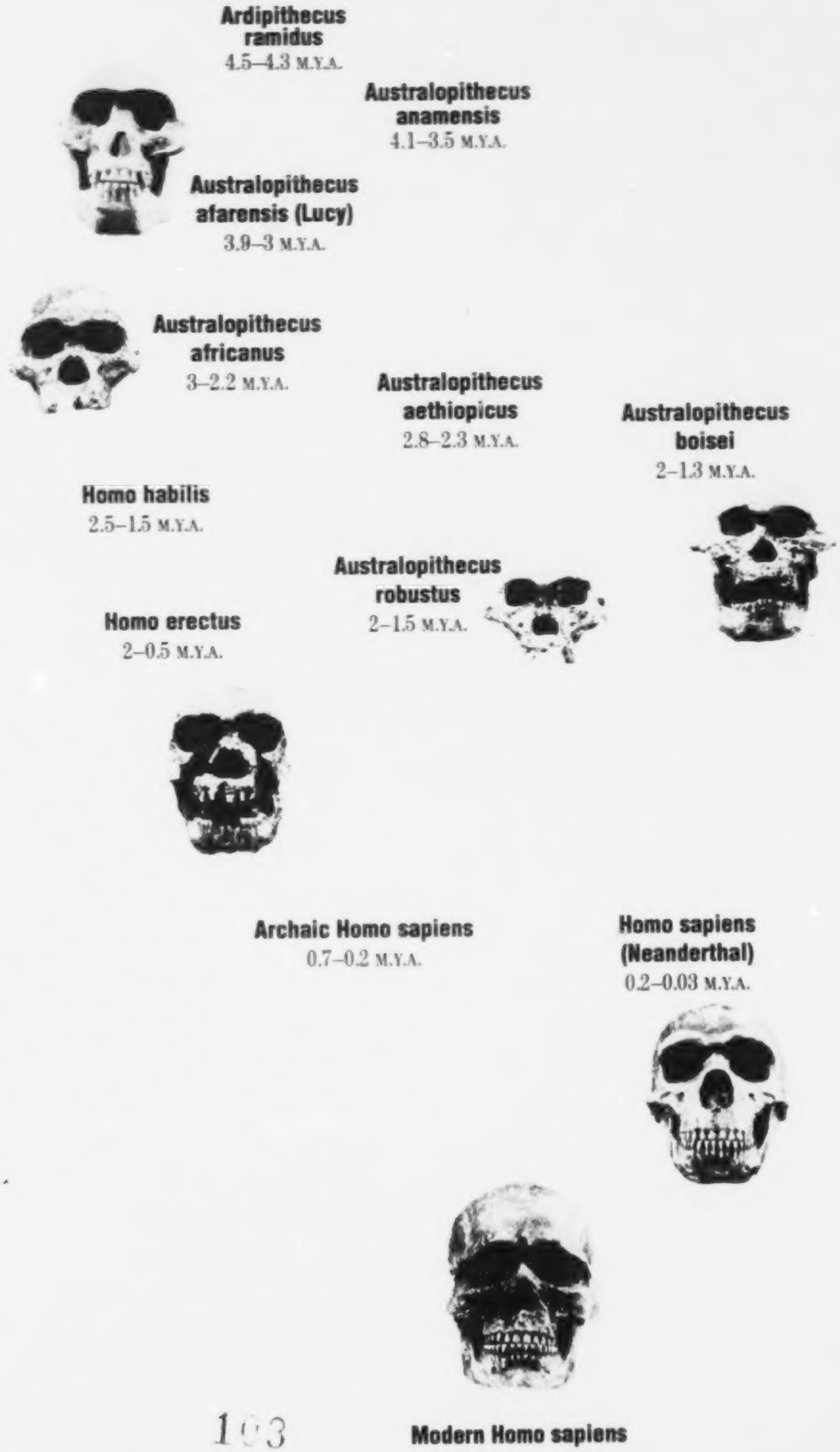
hominids



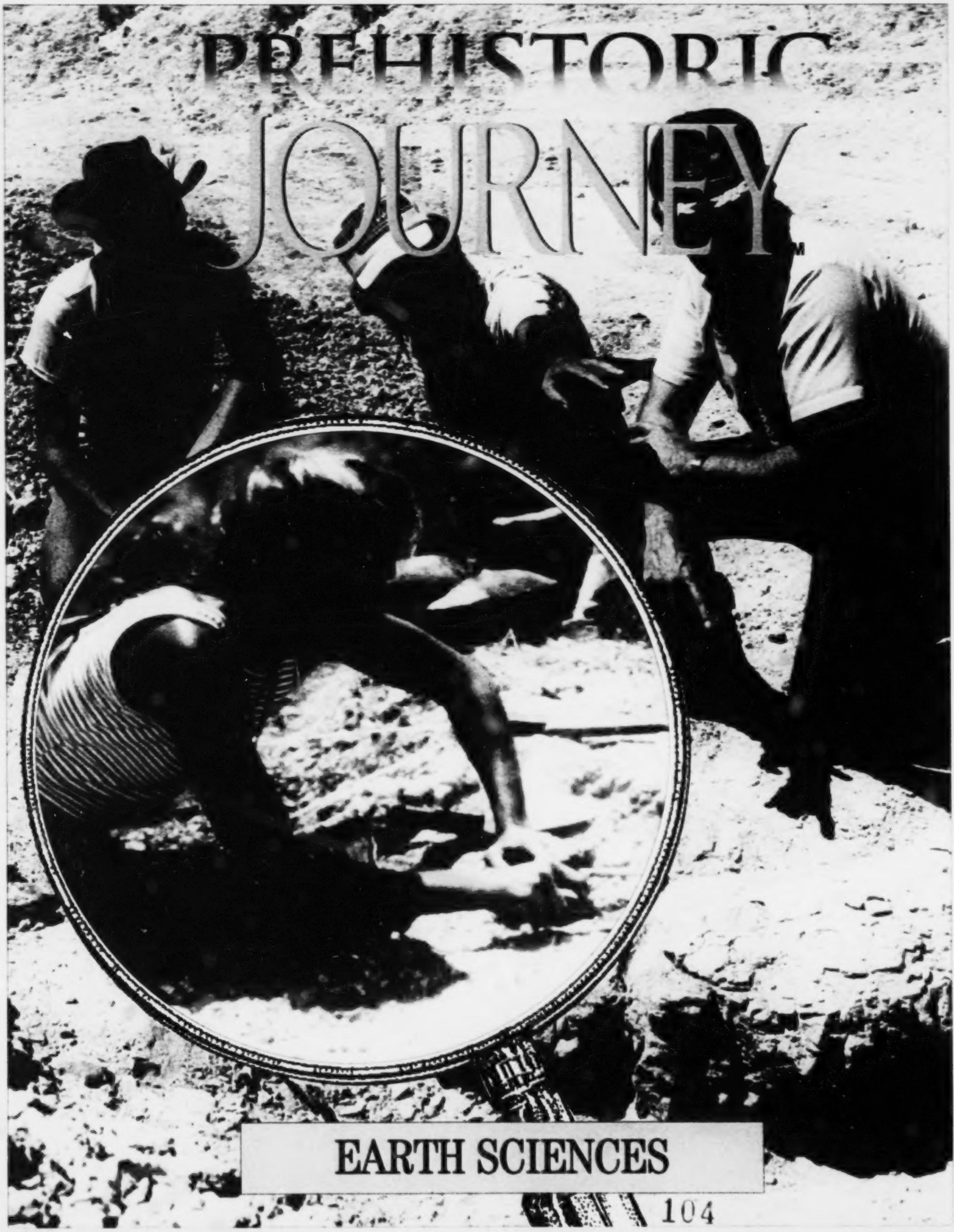
3

THE STORY OF US

Fossil skulls play an important role in piecing together the complexities of the 4-million-year-old human family. Hundreds of fossils from many different hominid species have been found so far, with more discoveries and more scientific debate taking place every day.


Ardipithecus ramidus
4.5–4.3 M.Y.A.
Australopithecus anamensis
4.1–3.5 M.Y.A.
Australopithecus afarensis (Lucy)
3.9–3 M.Y.A.
Australopithecus africanus
3–2.2 M.Y.A.
Australopithecus aethiopicus
2.8–2.3 M.Y.A.
Australopithecus boisei
2–1.3 M.Y.A.
Homo habilis
2.5–1.5 M.Y.A.
Australopithecus robustus
2–1.5 M.Y.A.
Homo erectus
2–0.5 M.Y.A.
Archaic Homo sapiens
0.7–0.2 M.Y.A.
Homo sapiens (Neanderthal)
0.2–0.03 M.Y.A.
Modern Homo sapiens

© DMNH Photo Archives/Rick Wicker



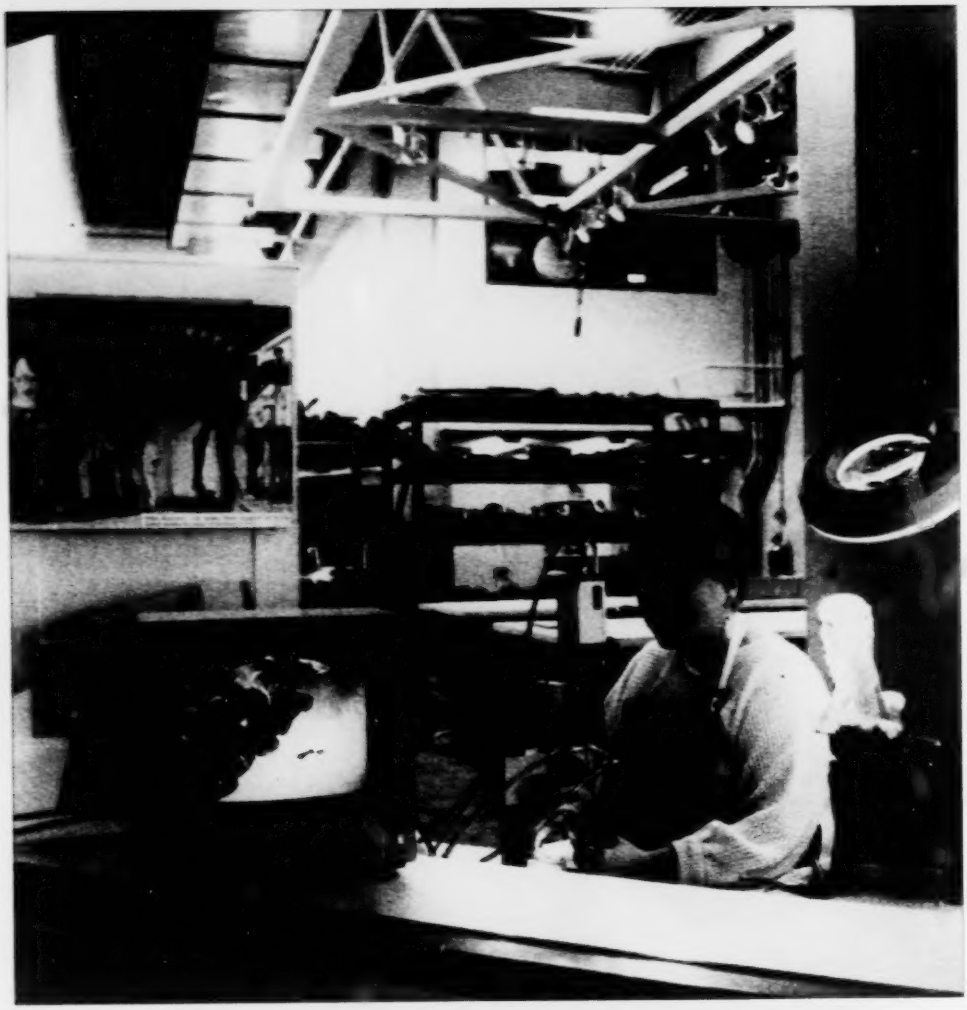
PREHISTORIC JOURNEY™

EARTH SCIENCES

BEST COPY AVAILABLE

PALEONTOLOGY LABORATORY

FOSSIL PREPARATORS AT WORK
Schlessman Family Foundation
Laboratory of Earth Sciences
Denver, Colorado
Holocene Epoch



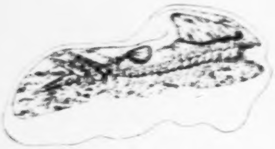
UNEARTHING THE PAST

SCIENTISTS AND TECHNICIANS HAVE MANY TOOLS AT THEIR DISPOSAL. Here, they use modern technology and human dexterity to uncover the mysteries of the fossil record.

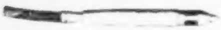
It has been 20 million years since the landscape of the Nebraska Woodland opened up. Some 4 million years—more than 250,000 generations—have passed since hominids climbed down from African trees.

Plastic
Hardener

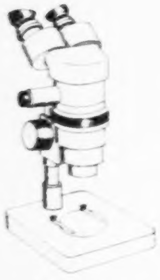
plastic hardener for preserving fossils



plaster field jacket with fossil

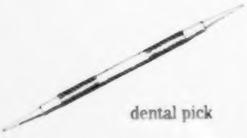


air scribe



microscope

glue



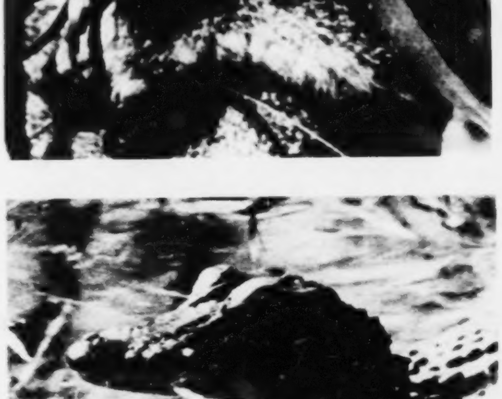
dental pick

The Earth has a History, and a Future.

> *"There is grandeur in this view of life . . .*
> *from so simple a beginning endless forms*
> *most beautiful and most wonderful have*
> *been, and are being, evolved."*
>
> Charles Darwin

BEST COPY AVAILABLE

The journey continues . . .



BEST COPY AVAILABLE

PREHISTORIC JOURNEY℠

TOURS AND INVESTIGATIONS

PREHISTORIC JOURNEY SOURCEBOOK AND COLORADO STATE TEACHING STANDARDS

The chart below is a quick reference that correlates the Colorado State Standards with the teaching materials in this Sourcebook.

Each tour contains information relevant to some of the standards. In addition, some of the standards may be addressed in the Tour's corresponding Investigation Units, which include pre-, during- and post-Museum visit activities.

For example, some simple reading activities may be appropriate during the K–3 Dinosaur and other Prehistoric Life Tour, but most of the reading activities are included in the *How Do You Measure Up* Investigation Unit. The science standards listed after the Tours and Investigations are followed by a series of numbers correlated to the specific standards addressed. Other content area standards simply refer to the overall state standards listed in the appendix. The interdisciplinary nature of these programs will be determined by the amount of time dedicated to pre- and post-visit activities and by the particular curriculum needs of your class. Feel free to use these interdisciplinary ideas, Tours, and Investigations to create your own innovative programs.

For more information about standards turn to pages 184–186 at the back of this Sourcebook.

Based on the Colorado Content Standards for Science

		SCIENCE STANDARD								OTHER STANDARD		
		1	3	3.1	3.4	4	4.1	5	6	Math	Geography	Reading
TOURS												
GUIDED:												
Dinosaurs and Other Prehistoric Life	(Grades K–3)		●	●	●	●	●			●		●
Ecosystems and Adaptations	(Grades 3–8)		●	●	●	●	●	●	●		●	●
How Do We Know? Advanced Ecosystems and Adaptations	(Grades 6–12)	●	●	●	●	●	●	●	●	●	●	●
SELF–GUIDED:												
Experiencing Evolution	(Grades 4–12)		●	●	●	●	●		●		●	●
Earth Processes: How Do We Know?	(Grades 6–College)	●	●	●	●	●	●	●	●	●	●	●
INVESTIGATION UNITS												
How Do You Measure Up?	(Grades K–4)		●	●	●	●	●			●		●
Fossil Leaf Litter	(Grades 4–8)	●	●	●	●	●	●	●	●	●		●
Sherlock Bones	(Grades 6–College)	●	●		●		●	●	●	●		●

Adopted 5/10/95 *Printed 6/2/95*

HITTING THE TRAIL

GUIDED TOURS

INVESTIGATIONS

We have also created ***Investigation Units,*** which are activities to accompany each tour (guided or self-guided).

Each Investigation includes:

- A pre-visit activity that covers recommended introductory concepts
- An activity to do while you are visiting the exhibit
- A post-visit activity that covers follow-up concepts
- Other related activities

Three guided tours are currently being offered in *Prehistoric Journey*. These tours were selected with input from area K–12 teachers.

To register for the guided tours, please call **322-7009.**

Dinosaurs and Other Prehistoric Life

Approximate length: 45 minutes
Suggested grades: K–3

Track down the dinosaurs of *Prehistoric Journey* while exploring ancient environments of the world before, during, and after the dinosaurs. Take a thrilling hike through a dinosaur creekbed environment and see spectacular dinosaur skeletons, learning what we know about dinosaur lifestyles and behavior, and what made the dinosaurs different from other prehistoric animals and animals of today. Touch real fossils along your journey and visit the fossil preparation laboratory.

Ecosystems and Adaptations

Approximate length: 45 minutes–1 hour
Suggested grades: 3–8

Trace the evolution of life on Earth, exploring re-creations of ancient ecosystems from the earliest living things undersea to the world of dinosaurs and ancient mammals. View spectacular fossils, learning how the adaptations of prehistoric animals and plants allowed them to function in ancient environments. Learn how events in the Earth's past are critical to understanding the future of our planet. Touch real fossils along your journey and visit the fossil preparation laboratory.

How Do We Know? Advanced Ecosystems and Adaptations

Approximate length: 1 hour–1 hour and 15 minutes
Suggested grades: 6–12

Ask the question, "How do we know?" while tracing the evolution of life on Earth through re-creations of ancient ecosystems from the earliest living things undersea to the world of dinosaurs and ancient mammals. Explore the methods scientists use to understand the past, including the examination of fossil evidence, geological evidence, applications of new technologies, and experimentation. View spectacular fossils, learning how the adaptations of prehistoric animals and plants allowed them to function in ancient environments. Learn how events in the Earth's past are critical to understanding the future of our planet. Touch real fossils along your journey and visit the fossil preparation laboratory.

GUIDED TOUR:

Dinosaurs and Other Prehistoric Life

RELATED INVESTIGATION:
How Do You Measure Up?
See pages 119–131

GUIDED TOURS:

Ecosystems and Adaptations

and

How Do We Know? Advanced Ecosystems and Adaptations

RELATED INVESTIGATIONS:

Fossil Leaf Litter
See pages 132–145

Sherlock Bones
See pages 146–156

BLAZING YOUR OWN TRAIL

SELF-GUIDED TOURS

TEACHER TIP

We designed these two self-guided tours to help you get the most out of your time in Prehistoric Journey. *Remember, there is a lot of information, and if you need to modify the tour or allow your students time to digest everything, please do so. You can always come back again!*

Pam Schmidt
Eighth Grade teacher
Thunder Ridge Middle School
and
Thom Adorney
Fourth Grade teacher
Kiffin Elementary School

SELF-GUIDED TOURS:

Experiencing Evolution
and
Earth Processes

RELATED INVESTIGATIONS:

Fossil Leaf Litter
See pages 132–145

Sherlock Bones
See pages 146–156

The following two suggestions for self-guided tours are presented in this section. The tours were developed by local K–12 teachers to provide you with ideas for using *Prehistoric Journey* to enhance your curricula in evolution and earth sciences.

EXPERIENCING EVOLUTION
Approximate length: 1 hour
Suggested grades: 4–12

EARTH PROCESSES: HOW DO WE KNOW?
Approximate length: 1 1/4 hours
Suggested grades: 6–College

If these tours are aimed at a higher grade level than you teach, or if you would like to focus on a different subject in your self-guided tour, create your own tour—plan the tour experience that you would like your students to have in the exhibit. Consult the *Come Take a Trail Through Time* exhibit layout and content pages that give exhibit component titles, teaching points, and things to do, and plan your path through *Prehistoric Journey*. You may need to enlist the help of a student aid or parent to take half of your group on the planned path while you take the other half of the class, since group size is limited.

THE TOUR

Keep a Trail Guide or map of Prehistoric Journey on hand throughout your tour. All tours begin with a brief introductory video in the **Time Travel Theater**. After leaving this area, move to the first diorama, the **Ancient Sea Floor**. Each diorama has an Evidence Case beside it displaying the scientific evidence for how we know what the area looked like in the past. Students should be given a brief amount of time to examine each of the dioramas you choose to focus on and its evidence.

RELEVANT DISPLAYS AND CORRESPONDING QUESTIONS

Each tour indicates relevant display headings in the exhibit where you should stop on your tour and focus on exhibit elements with your students. There are suggested questions related to the exhibit elements to be focused on in the tours.
These questions should be used to encourage critical thinking in your students. The right answer is not as important as the thought process the questions should inspire. Some questions have hints provided for the teachers, and many are answered in the text of the exhibit element focused on. Content information in other parts of this Sourcebook also relates to many of the questions.

MARGIN SYMBOLS

Symbols in the margins of each self-guided tour will provide the following information:

PACING YOUR TOUR

The tour is divided into
1/4-hour segments,
that are indicated by
the clock icon. These are
to help you pace your tour.

KEY CONCEPT

This key symbol
points out important
basic science concepts.

OPTIONAL

TOUR ELEMENTS

We have indicated optional elements that can be added or subtracted from your tour depending on time constraints.

EXPERIENCING EVOLUTION

SELF-GUIDED TOUR

APPROXIMATE LENGTH
1 hour

SUGGESTED GRADES
4–12

RELATED BACKGROUND INFORMATION

Turn to pages 45–47, 93–95 in this Sourcebook.

EVIDENCE AREA MAPS

Bring the Evidence Area Maps

pages 25, 36, 43, 51, 60–61, 79, 90

RELATED STANDARDS

Colorado State Science Standards are correlated with this tour on page 101 of this Sourcebook.

STANDARD 3.4:

Students know and understand how organisms change over time in terms of evolution and genetics.

INTRODUCTION

This tour is designed to highlight the parts of *Prehistoric Journey* that explain the process of how life has changed through time. While the whole exhibit addresses this topic to varying degrees, we have selected specific areas upon which to focus. Remember, this tour outline is only a guide.

Be sure to take advantage of the design of the exhibit: After visiting many of the Evidence Areas and learning more about that time in life's history, students can view the dioramas again with "new eyes."

Before beginning, introduce your tour, explaining what you would like students to look for on their journey, and what you want them to learn along the way (refer to the DURING THIS TOUR YOUR STUDENTS WILL section to the right).

DURING THIS TOUR YOUR STUDENTS WILL

- Learn how plants and animals evolved through time.
- Discover how environmental factors can drive natural selection.
- Focus on critical events in evolutionary history, such as life moving from the seas onto land, and the development of flight.

KEY TOUR CONCEPTS

The origin of life
Time Station concepts
Origin of the vertebrates
Leaving the water
Evolution and natural selection
Extinction
The reptile family tree
Primate evolution
The mammal family tree
Speciation
Human evolution

IMPORTANT TIME STATION ELEMENTS

Where Are You in Time?
The Setting
Era Highlights
Birth Announcements
Obituaries

TIME TRAVEL THEATER

Travel through time and begin your *Prehistoric Journey.*

ANCIENT SEA FLOOR DIORAMA

Proceed to the **Ancient Sea Floor Diorama** (Australia, 600 million years ago).
Note to your classroom that the first life was undersea.

EARLY LIFE EVIDENCE AREA

Move clockwise around the **Early Life** Evidence Area, beginning with the Evidence of an Ancient Sea Floor exhibit case.

RELEVANT DISPLAYS AND CORRESPONDING QUESTIONS

KEY CONCEPT

The Origin of Life

- Look at the "Recipe for Life." Note that the study of evolution involves extensive experimentation. *Is this something you could do at home?*
- Then see the "Replicating Life in the Lab?" panel.

Living Cells

*Why does **sexual reproduction** lead to more variation than **asexual reproduction**?*

Pollution Alert

- Stop at the "Pollution Alert" panel. Read the title and ask, *How could there be pollution in a prehistoric (pristine) environment?*

The Explosion of Life

- Note that 99 percent of the organisms that have ever lived are extinct.

OPTIONAL

Bones, Teeth, Shells, and Wood

Why was the development of hard parts an important evolutionary innovation?

KEY CONCEPT

PALEOZOIC TIME STATION

Move to the **Paleozoic Time Station.** This is the first of three Time Stations in *Prehistoric Journey*.
Which time model is easiest for you to relate to? Why?

SEA LILY REEF DIORAMA

Move to the **Sea Lily Reef** (Wisconsin, 425 million years ago) and point out to your students the great diversity of life in the seas.

DIVERSITY IN THE SEA EVIDENCE AREA

Move counterclockwise around the **Diversity in the Sea** Evidence Area, beginning with the Evidence of a Sea Lily Reef exhibit case.

RELEVANT DISPLAYS AND CORRESPONDING QUESTIONS

OPTIONAL

Places to Live in the Sea

What adaptations would animals need to live: near a rocky shore? in the open water?

- Play the "Where's My Home" Game.
  Think of an aquatic animal that you know that follows the "rules of the game."
- Watch the Reef Life video.
  How have reefs changed through time?

Brachiopod Diversity

Show on the Brachiopod Diversity panel where some groups of brachiopods nearly went extinct, but then survived.

KEY CONCEPT

Fish Story and its sloping panel, "The First Vertebrate Body Plan"
How is your body plan similar to that of a fish?

PACING YOUR TOUR

TRAILSIDE DISCOVERY CAMP

Before you go upstairs, on the right side of the Trail you'll find the **Trailside Discovery Camp.** If available, you can use this area for a brief rest and review of the first part of the exhibit.

KEY CONCEPT

LEAVING THE WATER STAIRCASE

Remind your students that everything you've seen so far was aquatic. All life for the first 3 billion years was underwater. As your class climbs the stairs, they are reenacting the first life-forms coming onto land.

BETWEEN TWO WORLDS DIORAMA

At the top of the stairs you'll see the **Between Two Worlds** Diorama (Wyoming, 395 million years ago). Note that early plants and animals are beginning to colonize land. How does life on land compare to life in the Sea Lily Reef?

LEAVING THE WATER EVIDENCE AREA

Proceed counterclockwise through the Leaving the Water Evidence Area, beginning at the Evidence for Between Two Worlds exhibit case.

RELEVANT DISPLAYS AND CORRESPONDING QUESTIONS

Living on Land

- Look at "What Does It Take?" then ask,
  How do you (a human) meet the three requirements necessary to live on land?
- At "Living on Land" ask,
  What is an example of an arthropod today that can live in water and on land?

Plants Changed the World

What would happen if we took all the plants off the Earth?

At Home in Two Worlds

What forces would favor animals that could move out of the water and onto land?

- View Mudskipper video.

Fish out of Water

- Read sloping panel that goes with "All About Amphibians."
  Identify the similarities between ancient fish and the first amphibian.

KEY CONCEPT

How Evolution Works

- Cover this thoroughly.

OPTIONAL

Natural Selection

- Choose two students to demonstrate the interactive computer activity for the rest of the group (this will take about 3–5 minutes).

Evolution Watch!

How does rate of reproduction affect evolution?

OVERLOOK

Before moving to the next area, take a moment to review appropriate behavior. You are coming up on two overlooks—parts of the exhibit that you will **look down into.** Keep your eye on students to ensure that they are not roughhousing and do not drop items over the railings.

KANSAS COASTLINE DIORAMA

Next you will see the **Kansas Coastline** (Kansas, 295 million years ago). Have students look at what life in the early forests was like.

FORESTS AND FLIGHT EVIDENCE AREA

After looking at the Diorama, turn and walk clockwise through the **Forests and Flight** Evidence Area, beginning with the Evidence of a Kansas Coastline exhibit case.

PACING YOUR TOUR

KEY DISPLAYS AND CORRESPONDING QUESTIONS

Insects Begin to Fly

Why was the evolution of flight such a great invention?

FORESTS AND FLIGHT EVIDENCE AREA (continued)

Amphibians Become Reptiles
Look at the *Seymouria* skeletons.
How can genetics explain an animal with amphibian and reptile features like Seymouria?

Showdown in North Texas
Look at the reconstruction of the *Dimetrodon*, the fin-backed protomammal. This animal is commonly mistaken as a dinosaur, but it is actually an early ancestor of mammals.

Excellent Eggs and Super Seeds
How are eggs and seeds similar?

First Forests
What conditions would favor a plant that could grow tall?
Once plants could grow tall, how would that affect other plants and animals?

KEY CONCEPT

Extinction Episode
Note to your students that this was the greatest extinction of all times, much greater than the better known extinction of the dinosaurs at the end of the Cretaceous Period.

OPTIONAL

Victims of the Permian Extinction
Pick one or two causes of extinction and discuss why it (they) cause extinctions.

MESOZOIC TIME STATION

Proceed to the **Mesozoic Time Station.** Address the elements relevant to this tour.

DINOSAUR OVERLOOK

Students will want to pause here to look down into the Time of the Dinosaurs Evidence Area (where dinosaur skeletons are reconstructed).

CRETACEOUS CREEKBED ENVIRORAMA

Descend the stairway into the **Cretaceous Creekbed** (North Dakota, 66 million years ago).
Don't forget that this Envirorama represents the **end** of the time of dinosaurs.
Find the mammals in this scene?

- RELATED INVESTIGATION—FOSSIL LEAF LITTER (see pages 132–143)

TIME OF THE DINOSAURS EVIDENCE AREA

Proceed through the **Time of the Dinosaurs** Evidence Area, which begins with the Evidence of a Cretaceous Creekbed exhibit case. Remember that dinosaurs are but one chapter in the history of life. In order to complete your tour in a timely manner, we recommend that you allow students to enjoy the dinosaur skeletons, but focus primarily on the displays specifically related to this tour.

RELEVANT DISPLAYS AND CORRESPONDING QUESTIONS

KEY CONCEPT

The Reptile Family Tree and What Is a Dinosaur?
How are mammals and dinosaurs related?

Flying Reptiles and Early Birds and sloping panel "Ways to Wing It"
Explain the idea of **convergent evolution** in your own words.
Can you give an example besides flight? What selective forces would favor the evolution of flight?

- Look at the *Archaeopteryx* fossil, then ask,
  What features does it have that are like a bird? What features are like a reptile?

PACING YOUR TOUR

A World Without Flowers
Point out that plants developed flowers, making it possible for them to reproduce more rapidly, thus allowing them to better compete with slow-growing plants.
What are some ways that the evolution of flowering plants might have affected the evolution of other organisms?

TIME OF THE DINOSAURS EVIDENCE AREA (continued)

Swimming in the Sea

This ammonite shows evidence of predation by a mosasaur. Find the evidence.
Look at the teeth in the mosasaur skeleton above the fish on the wall.

OPTIONAL

- Watch the video (approximately 5 minutes long)—**The End of the Dinosaurs.**

KEY CONCEPT

CENOZOIC TIME STATION

At the **Cenozoic Time Station** address the elements relevant to your tour.

RAINFOREST TREETOP DIORAMA

Move on to the **Rainforest Treetop** (Wyoming, 50 million years ago).

TROPICAL ROCKIES EVIDENCE AREA

After viewing the Diorama, proceed to your right through the Tropical Rockies Evidence Area in a counterclockwise manner, beginning with the **Evidence of a Rainforest Treetop** exhibit case.

RELEVANT DISPLAYS AND CORRESPONDING QUESTIONS

Life After the Dinosaurs

Why did the mammals change?

KEY CONCEPT

Our Legacy of Life in the Trees

- Read the sloping panel "Look Familiar," then ask,
  What are some things about your body that had already evolved in the primates of 50 million years ago?

Rhinos in North America?

- RELATED INVESTIGATION—SHERLOCK BONES (see pages 146–156)

KEY CONCEPT

Ancestors of Modern Mammals and What Is a Species?

- Study the mammal ancestors panel and discuss the study element on Species.

NEBRASKA WOODLAND ENVIRORAMA

Next go to the **Nebraska Woodland** (Nebraska, 20 million years ago).
What behavioral adaptations might these camels have evolved to escape from Dinohyus?

EXPANDING GRASSLANDS EVIDENCE AREA

Proceed through the Expanding Grasslands Evidence Area, beginning at the **Evidence of a Nebraska Woodland** exhibit case.

RELEVANT DISPLAYS AND CORRESPONDING QUESTIONS

Horse Tale

What do you think caused horses to go extinct in North America 8,000 years ago?

KEY CONCEPT

The Story of Us

Did humans evolve from modern monkeys and apes?
(No. Humans share a **common ancestor** with modern monkeys and apes.)

The Sleeping Tree

What australopithecine features are adapted for tree-dwelling? What features are adapted for walking on the ground? What do we have in common with Australopithecus? *(What makes us both hominids?)*

PACING YOUR TOUR

Life in the Cenozoic Seas

- Stop at this panel and **before reading, ask,**
  How can you explain the tiny legs on the whale Basilosaurus?

BEST COPY AVAILABLE

PALEONTOLOGY LABORATORY

After leaving the **Expanding Grasslands** Evidence Area you will see the **Paleontology Laboratory** where your students will have the opportunity to see Museum staff and volunteers preparing fossils.

FOLLOW-UP QUESTIONS

Does anyone remember where life began and how long ago that happened?

What had to happen to the animals and plants that lived underwater to allow them to move onto land?

When was Denver a tropical paradise?

After taking your journey through time, why do you think it is important for us to explore and study the ancient past?

WRAP-UP

In our tour today we have learned how living things have changed through time and how Earth's changing environment has been an important force in natural selection. We have seen critical events in life's history, and the evidence that scientists use to understand these events.

EXPANDING YOUR TOUR

If you want to expand your tour and study of evolution into the rest of the Museum, the following exhibits will be helpful.

EXHIBIT	**MUSEUM HALL**	**FLOOR**
Human Evolution	Hall of Ancient Peoples	1
Darwin on the Galapagos Islands	South American Hall	3
Whale Skeleton	Scenic Lounge	2
Insects	Atrium	1
Zebra Skeleton Exhibit	Botswana Africa Hall	3
Rare Birds	Rare Birds Hall	3

BEST COPY AVAILABLE

EARTH PROCESSES: HOW DO WE KNOW?

SELF-GUIDED TOUR

APPROXIMATE LENGTH

1 1/4 hours

SUGGESTED GRADES

6–College

RELATED BACKGROUND INFORMATION

Turn to pages 26–31, 37, and 52 in this Sourcebook.

EVIDENCE AREA MAPS

Bring the Evidence Area Maps.

pages 25, 36, 43, 51, 60–61, 79, 90

RELATED STANDARDS

Colorado State Science Standards are correlated with this tour on page 101 of this Sourcebook

STANDARD 4.1:

Students know and understand the composition of Earth, its history, and the natural processes that shape it.

INTRODUCTION

This tour is designed to explain geological processes and how scientists know what happened in the past. While all of the exhibit addresses this topic to varying degrees, we have selected specific areas upon which to focus. Remember, this tour outline is only a guide.

Be sure to take advantage of the design of the exhibit: After visiting many of the Evidence Areas and learning more about that time in life's history, students can view the dioramas again with "new eyes."

Before beginning, introduce your tour, explaining what you would like students to look for on their journey, and what you want them to learn along the way (refer to the DURING THIS TOUR YOUR STUDENTS WILL section to the right).

DURING THIS TOUR YOUR STUDENTS WILL

- Explore the methods scientists use to understand the past.
- Explore methods of dating fossils and rock layers.
- Study how rock layers and fossils form.
- Discover techniques Museum scientists and paleontologists use to acquire and prepare fossils and to reconstruct ancient environments and their inhabitants.
- Learn that interpreting events in the Earth's past is critical to understanding the future of our planet.

KEY TOUR CONCEPTS

Evidence for the dioramas
The age of the Earth
Concepts at the Time Stations
Relative dating of rock layers
Fossilization
Evolution
The greenhouse effect
Extinction
Sedimentation
Taphonomy
Climate

IMPORTANT TIME STATION ELEMENTS

Where Are You in Time?
Environmental Conditions
Where's Colorado?

TIME TRAVEL THEATER

Travel through time and begin your *Prehistoric Journey.*

Based on the video we just saw, where did the water on the early Earth come from?

(Gases, including steam, escaped from volcanoes. The steam cooled and condensed to form water.)

ANCIENT SEA FLOOR DIORAMA

Proceed to the **Ancient Sea Floor Diorama** (Australia, 600 million years ago). Note to your classroom that the first life was undersea.

EARLY LIFE EVIDENCE AREA

Move clockwise around the **Early Life** Evidence Area, first stopping to look at the **Evidence of an Ancient Sea Floor**.

RELEVANT DISPLAYS AND CORRESPONDING QUESTIONS

KEY CONCEPT

Evidence of an Ancient Sea Floor

Introduce students to the fact that each diorama is accompanied by an Evidence Case. Ask them to draw correlations between what is presented in this case and the Diorama.

KEY CONCEPT

How Old Is the Earth?

- Have students use the Geiger counter and touch the oldest rock on Earth. Explain that radiometric dating is used to determine the age of the Earth. Then ask,
  How can we grasp the immensity of 4.5 billion years?

How Radiometric Dating Works

- Interpret information on radiometric dating for students.

OPTIONAL

- Have students use the graph to answer the question at the bottom of the panel (as space is limited, this may be difficult, unless small groups of students work on this at different times).

Explosion of Life

- Look at the sloping panel "99 percent of all organisms . . ." and ask,
  How do we know that these organisms ever lived? (We find their fossils.)
  The first hard parts evolved at the time of the Cambrian Explosion. Could that be influencing our idea that life exploded at this time?
  (Since organisms with hard parts are more likely to be preserved in the fossil record, scientists must take this into account when determining abundance of organisms in the past.)

Bones, Teeth, Shells, and Wood

- After reading, ask the following questions
  What part of your body would most likely be fossilized and why? (Teeth and bones.)
  Why do you think hard parts are much more likely to fossilize than soft parts?

PALEOZOIC TIME STATION

Move to the **Paleozoic Time Station.** This is the first of three Time Stations in the exhibit. Focus on "Where Are You in Time," "Environmental Conditions," and "Where's Colorado?"—the plate tectonics interactive.

When has Colorado been below the equator?

SEA LILY REEF DIORAMA

Move to the **Sea Lily Reef** Diorama (Wisconsin, 425 million years ago) and point out to your students the great diversity of life in the seas. Then move counterclockwise around the **Diversity in the Sea** Evidence Area.

RELEVANT DISPLAYS AND CORRESPONDING QUESTIONS

PACING YOUR TOUR

DIVERSITY IN THE SEA EVIDENCE AREA

Evidence of a Sea Lily Reef

Based on the evidence, would you have reconstructed the Diorama the way the Museum did?

DIVERSITY IN THE SEA EVIDENCE AREA (CONTINUED)

Life in the Paleozoic Seas

How were Ohio and Minnesota different 450 million years ago than they are today? What evidence indicates the difference?

- Show students the sloping panel "350-million-year-old sea lilies . . ."
  Why do you think it would be difficult to determine whether an organism was a plant or an animal? How would you know? (One way is to compare with animals and plants living today.)

Trilobites Through Time

- Stop at "One Trilobite, Many Fossils."
  Point out that if we became fossils, we would only leave one skeleton. On the other hand, a single trilobite can leave many fossils because of the many shells it molts throughout its life—many fossils could represent only one living individual trilobite. Similarly, one tree can leave many fossil leaf imprints.

KEY CONCEPT

Which Rocks Are Older?

- Read, and do the interactive "Everything's Relative." Ask,
  How is the stack of newspapers similar to the chunk of sedimentary rock next to it?

KEY CONCEPT

How Things Turn to Stone

- Before reading the panel, ask students the initial question,
  What do water pipes have to do with fossils?
- Then direct students to read the panel and again ask the question. (The key point is that water passes through decaying organisms, leaving minerals behind.)

TRAILSIDE DISCOVERY CAMP

If available, you can use this area for a brief rest and review of the first part of the exhibit. Remind your students of some of the ways scientists date the past and how living things turn into fossils.

LEAVING THE WATER STAIRCASE

As your class ascends the stairs, they are reenacting the first life-forms coming onto land.

BETWEEN TWO WORLDS DIORAMA

At the top of the stairs you'll see the **Between Two Worlds** Diorama (Wyoming, 395 million years ago).

LEAVING THE WATER EVIDENCE AREA

Move counterclockwise through the Leaving the Water Evidence Area.

RELEVANT DISPLAYS AND CORRESPONDING QUESTIONS

Evidence of Between Two Worlds

See How do we know? Ask,

The reddish, U-shaped area marked with a ② used to be a river. Why is it so high above ground now? (The area was uplifted then the surrounding rock eroded away.)

KEY CONCEPT

How Evolution Works

- Ask students to study and interpret this display.

Plants Changed the World

- Read this panel and emphasize that plants changed the atmosphere, affecting the sky color, and altered the topsoil in a manner that supported more terrestrial life.

PACING YOUR TOUR

OVERLOOK

Before moving to the next area, take a moment to review appropriate behavior. You are coming up on two overlooks—parts of the exhibit that you will **look down into**. Keep your eye on students to ensure that they are not roughhousing and do not drop items over the railings.

KANSAS COASTLINE DIORAMA

Next you will see the **Kansas Coastline** Diorama (Kansas, 295 million years ago). Discuss what early forests looked like and how scientists today may know this.

FORESTS AND FLIGHT EVIDENCE AREA

Walk clockwise through the **Forests and Flight** Evidence Area.

RELEVANT DISPLAYS AND CORRESPONDING QUESTIONS

Evidence of a Kansas Coastline
Is this the type of evidence you expected from viewing the Diorama?

Insects Begin to Fly
What kind of sediment would have preserved fossils as delicate as the dragonfly wing?

First Forests

- Read the sloping panel that explains how once-living organisms are changed into ***sedimentary rock*** by geologic forces of heat and pressure. Point out that geologists mining for coal often find other fossils in coal beds.

KEY CONCEPT

From Ancient Plants to a Modern Greenhouse
What is the relationship between fossil fuels and the Greenhouse Effect?
What could happen to coastal regions and islands as a result of global warming?

300-Million-Year-Od Pennsylvanian Forest Floor

- Read the panel and then point out that replacement fossilization with white clay is extremely rare and yields a unique specimen.
- Have your students answer the questions at the bottom of the related panel.

Extinction Episode

- Discuss the variety of geologic and atmospheric activities that cause biological extinctions on land and in the oceans.
- Point out that this was the greatest extinction of all time, eliminating as much as 96 percent of all Permian species, then ask,
  What are some of the methods that scientists used to learn that the Permian extinction was the greatest extinction of all time?

KEY CONCEPT

KEY CONCEPT

MESOZOIC TIME STATION

Address the relevant elements of this display. Students will want to pause here to look down into the **Time of the Dinosaurs** Evidence Area (where the dinosaurs skeletons are reconstructed).

CRETACEOUS CREEKBED ENVIRORAMA

Descend the stairway into the **Cretaceous Creekbed** (North Dakota, 66 million years ago). Don't forget that this Envirorama represents the **end** of the age of dinosaurs. Pay particular attention to clues animals and plants left behind that could help modern scientists reconstruct this environment.

- RELATED INVESTIGATION—FOSSIL LEAF LITTER (see pages 132–143)

TIME OF THE DINOSAURS EVIDENCE AREA

Move through the **Time of the Dinosaurs** Evidence Area. While you may be tempted to stay here a long time, remind your students that dinosaurs are but one chapter in the history of life on Earth.

RELEVANT DISPLAYS AND CORRESPONDING QUESTIONS

Evidence of a Cretaceous Creekbed

- Compare the fossil leaves to their reconstruction.

PACING YOUR TOUR

Fleshing Out Dinosaurs

- A variety of fossilization processes yield information about how animals looked and moved.
  What types of fossilization processes could have created skin impressions? Ridges and depressions on bones?

TIME OF THE DINOSAURS EVIDENCE AREA (continued)

- Look at the sloping panel "What color were the dinosaurs?"
  What fossil evidence is there that indicates what color the dinosaurs were?

Touch a Triassic Tree

- Note that prehistoric Native Americans used petrified wood for making projectile points (arrowheads, spear points, and so forth) because its composition is similar to flint, chert, and obsidian. This is an amazing transformation considering the fibrous texture of wood.

The Long-Necked Dinosaur

- Look closely at the quarry map from Dinosaur National Monument.
  How do you suppose the bones ended up in this jumbled arrangement?
  How did the Morrison Formation get its name? (It was first identified in Morrison, Colorado.)

The Latest Word on Stegosaurus

- Stop at the panel and remind students that brains and skin are soft tissues.
  How is the cast of a brain formed differently than a skin impression?

OPTIONAL

Duckbills Were Good Parents

If you were a paleontologist in the field looking for dinosaur nests, how would you identify one after 80 million years?

Underwater Colorado

- Read and discuss this panel and the sloping panel. Point out that where you're standing now was once part of the Cretaceous Seaway.
- Discuss the relationship between oil and natural gas. Then ask,
  What are the names of three types of fossil fuels?

How Ammonites Tell Time

- The key point is that ammonite sequence and radiometric dating of ash can be combined to date rock layers very accurately.

KEY CONCEPT

The End of the Dinosaurs

- Point out that the Cretaceous-Tertiary (K-T) Boundary is marked by the layer of iridium and shocked quartz. Then ask,
  What other evidence shows that the world before the K-T Boundary was different from the world after?

CENOZOIC TIME STATION

Again, address the pertinent panels. Watch the temperature gauge as the continents move.
When was it the warmest?

RAINFOREST TREETOP DIORAMA

Turn to the **Rainforest Treetop** Diorama (Wyoming, 50 million years ago).

TROPICAL ROCKIES EVIDENCE AREA

The **Tropical Rockies** Evidence Area is laid out in a counterclockwise manner.

KEY DISPLAYS AND CORRESPONDING QUESTIONS

Evidence of a Rainforest Treetop

Have students identify four types of evidence for a tropical climate in this case.

PACING YOUR TOUR

KEY CONCEPT

Today's Rocks Are Yesterday's Sediments

- Watch this video (approximately 5 minutes long).

BEST COPY AVAILABLE

TROPICAL ROCKIES EVIDENCE AREA (continued)

Life After Dinosaurs
- Look at the evidence for a tropical climate in Denver.

Tropical Rockies
- Read. Compare the climate zone maps of 50 million years ago and today.
- Look at "Rich Records of Past Life," then ask,
  How is a lake like a photo album?

Fossil Palm
The panel discusses temperature. Ask,
Can you make any guesses about the amount of rainfall when this plant was alive?

Rhinos in North America?
- RELATED INVESTIGATION—SHERLOCK BONES (see page 146–156)

What Is a Species?
How can geologic forces contribute to the development of new species?

NEBRASKA WOODLAND ENVIRORAMA

Next go to the **Nebraska Woodland** Envirorama (Nebraska, 20 million years ago). After passing through the Envirorama, read and discuss the **Evidence of a Nebraska Woodland**. Go to the following displays in the **Expanding Grasslands** Evidence Area

RELEVANT DISPLAYS AND CORRESPONDING QUESTIONS

EXPANDING GRASSLANDS EVIDENCE AREA

Evidence of a Nebraska Woodland

Bed of Bones
- Before students read the panel, look at the bone bed, and ask,
  How do you think so many rhino bones ended up in one place?
- Have students read the panel. Point out that scientists don't believe these animals died at the same time.
  What evidence do you think could have led them to this conclusion?

KEY CONCEPT

Sherlock Bones and the Case of the Found Fossils
- Read thoroughly; discuss as appropriate for your group.

The Horse Tale
- Read the panel thoroughly. Point out that there is a relationship between environmental conditions and horse evolution. Changing climate caused the rainforest to change to patchy woodlands and change again to open grasslands . . . As a result, horses evolved higher crowned teeth to eat the tough grasses and legs that were better suited for running on drier, open ground. This is a classic example of climate change affecting biological change.

KEY CONCEPT

Creating Climates
How does knowing how climate has changed through time help scientists today?

PACING YOUR TOUR

Giant Bison
- Read the "Dating the Recent Past" information.

What type of material does Carbon 14 dating actually date? How is this different from other forms of radiometric dating, like potassium-argon and uranium-lead dating, which date things that are billions of years old?

PALEONTOLOGY LABORATORY

(Carbon-14 dating dates original organic material, and only material *under* 50,000 years old—many other types of radiometric dating date rock layers, not organic material.)
After leaving the Expanding Grasslands Evidence Area you will see the **Paleontology Laboratory** where your students will have the opportunity to see Museum staff and volunteers work on current fossils.

FOLLOW-UP QUESTIONS

After taking your journey through time, why do you think it is important for us to explore and study the ancient past?

How might living things and the Earth be different if the early primates had gone extinct at the end of the Eocene Epoch?

What are some of the questions about the history of the Earth and life that scientists are still trying to answer? Do you have any ideas for experiments or lines of investigation they (or you) should follow to try to answer these questions?

WRAP-UP

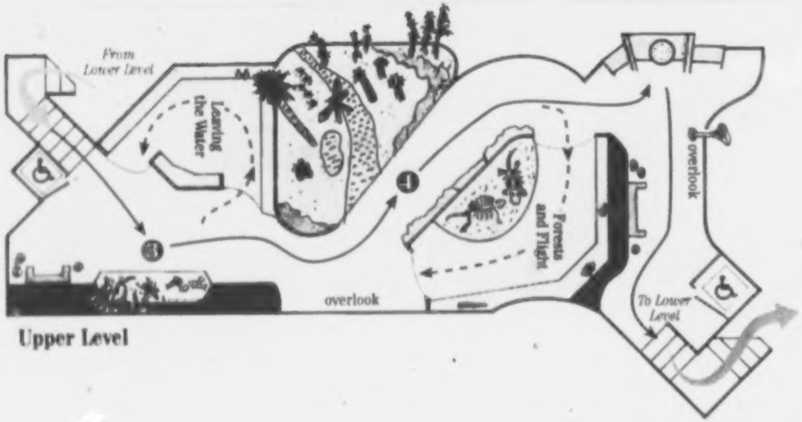
In our tour today we have explored the methods that scientists use to understand the past. We've learned how rock layers and fossils form, and we've learned about the techniques scientists use to find out how old rock layers and fossils are. Along our journey, we've had glimpses of the past and seen the evidence those reconstructions are based on. Most importantly, we have had the opportunity to see why studying the past is important to understanding the present and future of life on Earth.

EXPANDING YOUR TOUR

If you want to expand your tour and study of the Earth's processes into the rest of the Museum, the following exhibits will be helpful.

EXHIBIT	MUSEUM HALL	FLOOR
Earth—Past, Present, and Future	Earth Sciences Hall	1
A Passion for Discovery	Earth Sciences Hall	1
Planetarium Programs	Gates Planetarium	1
Gems and Minerals	Coors Mineral Hall	1
Colorado's Mining Heritage	Coors Mineral Hall	1

BEST COPY AVAILABLE


From Lower Level
Leaving the Water
❸
❹
Forests and Flight
overlook
overlook
To Lower Level

Upper Level

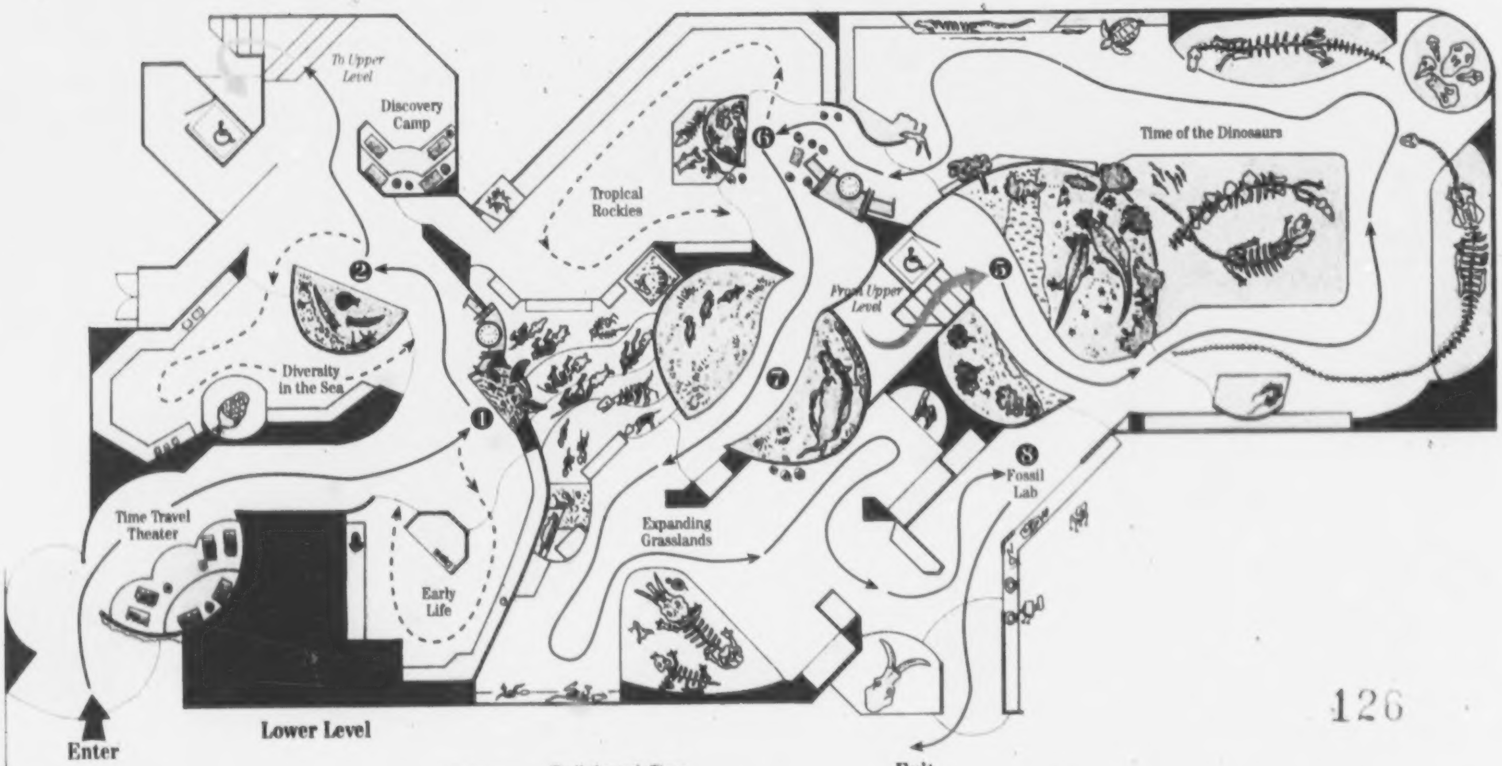
Diorama Scenes

❶ Ancient Sea Floor
❷ Sea Lily Reef
❸ Between Two Worlds
❹ Kansas Coastline
❺ Cretaceous Creekbed
❻ Rainforest Treetop
❼ Nebraska Woodland
❽ Earth Sciences Lab

There are lots of fossils you're allowed to touch in Prehistoric Journey.

But please leave the others alone, even if you can reach them.

Fossils are fragile and irreplaceable.


To Upper Level
Discovery Camp
Tropical Rockies
❻
❷
Diversity in the Sea
❶
Time Travel Theater
Early Life
Expanding Grasslands
❼
From Upper Level
❺
Time of the Dinosaurs
❽
Fossil Lab
Enter
Exit
to restrooms

Lower Level

Trail through Time
Suggested Evidence Area Path
Time Station

PREHISTORIC JOURNEY

125

126

BEST COPY AVAILABLE

INVESTIGATIONS

GRADE RANGE: K–COLLEGE

The following symbols are used throughout this section:

PRE-VISIT ACTIVITY

MUSEUM ACTIVITY

POST VISIT ACTIVITY

To complement your trek through *Prehistoric Journey*, we have designed (with the help of our Teacher Advisory group) related activities to do before, during, and after your visit. Each Investigation Unit contains a pre-visit activity that covers recommended introductory concepts, an activity to do while at the Museum, and a post-visit activity that covers follow-up concepts. These activities can be used together or pulled out and used separately. Along with these units, there are *Fun for Prehistoric Parents* pages to be copied and sent off to your students' parents and fun mini-activities that you could use or expand upon in your classroom.

There are three Investigation Units:

How Do You Measure Up?
(recommended for Grades K–4)

Fossil Leaf Litter
(recommended for Grades 4–8)

Sherlock Bones
(recommended for Grades 6–College)

HOW DO YOU MEASURE UP?

GRADE RANGE: K–4

DURING THIS UNIT YOUR STUDENTS WILL

- Measure and estimate sizes of dinosaur footprints, using their own feet for comparison.
- Estimate the sizes of various prehistoric animals.
- Take a trail through time in *Prehistoric Journey*, comparing the sizes of prehistoric animals and plants to the size of their own bodies.
- Learn what different dinosaurs and their environments looked like, and communicate this information by creating an ancient dinosaur habitat in the classroom.

OVERALL UNIT GOAL

To introduce students to the *Time of the Dinosaurs*, placing dinosaurs in context in prehistory, and using dinosaurs and other prehistoric life to develop student skills in measuring, estimating and comparing sizes, and expressing size comparison through art.

BACKGROUND INFORMATION

Dinosaurs were among the most successful animals that have ever lived. Dinosaurs evolved about 230 million years ago and went extinct 65 million years ago. During this span of 165 million years, some of nature's most awesome animals lived and died. The only real dinosaurs you'll ever see are fossils, but they were once much more than skeletons and footprints.

Prehistoric Journey gives visitors the opportunity to peek into this ancient world of dinosaurs. In preparing for the exhibit, Museum scientists and artists reconstructed these extinct giants by carefully collecting and studying fossils, drawing from every available clue to determine how dinosaurs looked and behaved when they were alive. Fossilized bones are not the only clues. Traces of dinosaur skin are preserved as impressions stamped into mud or wet sand. Other fossil impressions include footprints, which are measured to estimate size and speed of the dinosaurs. Skeletons and fossilized tracks tell us some dinosaurs traveled alone and some in herds; some ran fast and galloped, while others had a slow, meandering walk. Some could rear up on their hind legs; others could not. Some dinosaurs held their tails stiffly; others had whiplike tails. From the study of skulls and teeth, dinosaur diets can be determined. Comparing dinosaur skeletons, footprints, and other fossils with those of modern animals helps scientists make educated guesses about prehistoric anatomy, movement, metabolism, hunting strategies, and social behavior.

In *Prehistoric Journey*, dinosaurs are presented in the context of the whole history of life on Earth. Along the trail, students can size up the past, comparing the giant dinosaurs to other denizens of prehistory.

Throughout the history of life, the sizes of living things have changed. The earliest life-forms were microscopic—too small to see with the naked eye. The development of hard parts like shells, skeletons, and wood allowed animals and plants to grow very large. Early dinosaurs were small—not huge like the fearsome *Tyrannosaurus* or the giant *Diplodocus*. There are some obvious advantages to evolving large size, but there are disadvantages as well. It takes a lot of food to keep a large animal alive, and large animals have often died off during episodes of mass extinction.

RELATED TOURS

GUIDED:

Dinosaurs and Other Prehistoric Life

PRE-VISIT ACTIVITY

DINOSAUR FOOTPRINTS

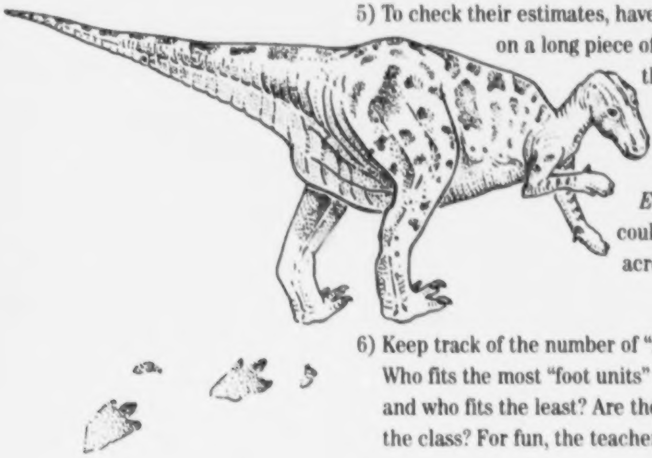
MATERIALS

Rulers
Yard/meter sticks
Butcher paper
Colored chalk
Colored pencils
Graph paper
Overhead sheet
Overhead projector
Copy of *Edmontosaurus* footprint

PREPARATION

Cut a large piece of butcher paper into a square measuring at least 68 cm x 70 cm for every student group.

Use an overhead projector to enlarge footprint and then trace, or use graph paper. Make a copy of the *Edmontosaurus* footprint for each student group. Show pictures of duck-billed dinosaurs.



ACTIVITY GOALS

- To introduce students to the scale of dinosaur footprints.
- To introduce the concept of units of measurement and give students the opportunity to measure objects.

METHODS

1) Tell the students that scientists have found large *Edmontosaurus* (duckbilled dinosaur) footprints. Ask students what they think an *Edmontosaurus* footprint looks like. Have them draw their idea of the footprint on a separate sheet of paper.

2) Show them the outline of the *Edmontosaurus* footprint. Working in groups of three to four, have students draw the footprint to scale onto their 68 cm x 70 cm piece of paper. (For younger students, the teacher may want to prepare the scale drawing of the footprint in advance for the class.)

3) Ask students to suggest ways in which they can measure the size of the footprint. What units can they use? What supplies do they need? What if they didn't have rulers?

4) Have students work in groups to trace their own footprint and then compare their footprint to that of the *Edmontosaurus*. Have them estimate how many of their footprints would fit inside the *Edmontosaurus* print.

5) To check their estimates, have the students create a "ruler" on a long piece of mural paper using cutouts of their footprints. Have them measure the *Edmontosaurus* print using their "foot" ruler. How many of their feet fit inside the *Edmontosaurus's*? (Students could also glue their footprints across the dinosaur print.)

6) Keep track of the number of "foot units" for each student. Who fits the most "foot units" in the *Edmontosaurus* track and who fits the least? Are their feet the biggest or smallest in the class? For fun, the teacher can participate to compare.

DISCUSSION

Was your idea of what the *Edmontosaurus* footprint looked like similar to the real footprint? Have them share their pictures with the class.

How many of your feet fit into the *Edmontosaurus* print?

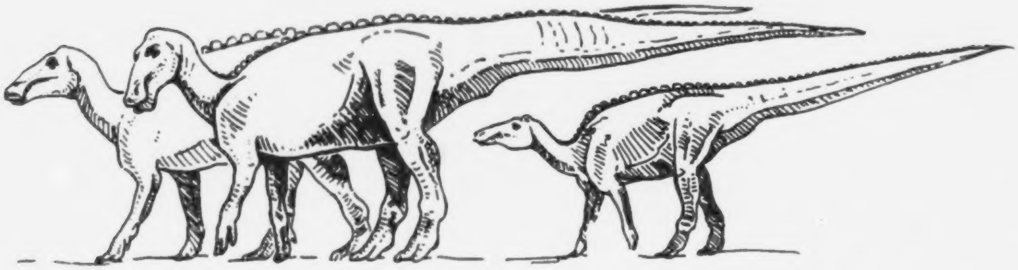
Can you think of any other ways to measure the dinosaur footprint without using a ruler?

How do you think the *Edmontosaurus* walked? (Have students demonstrate.)

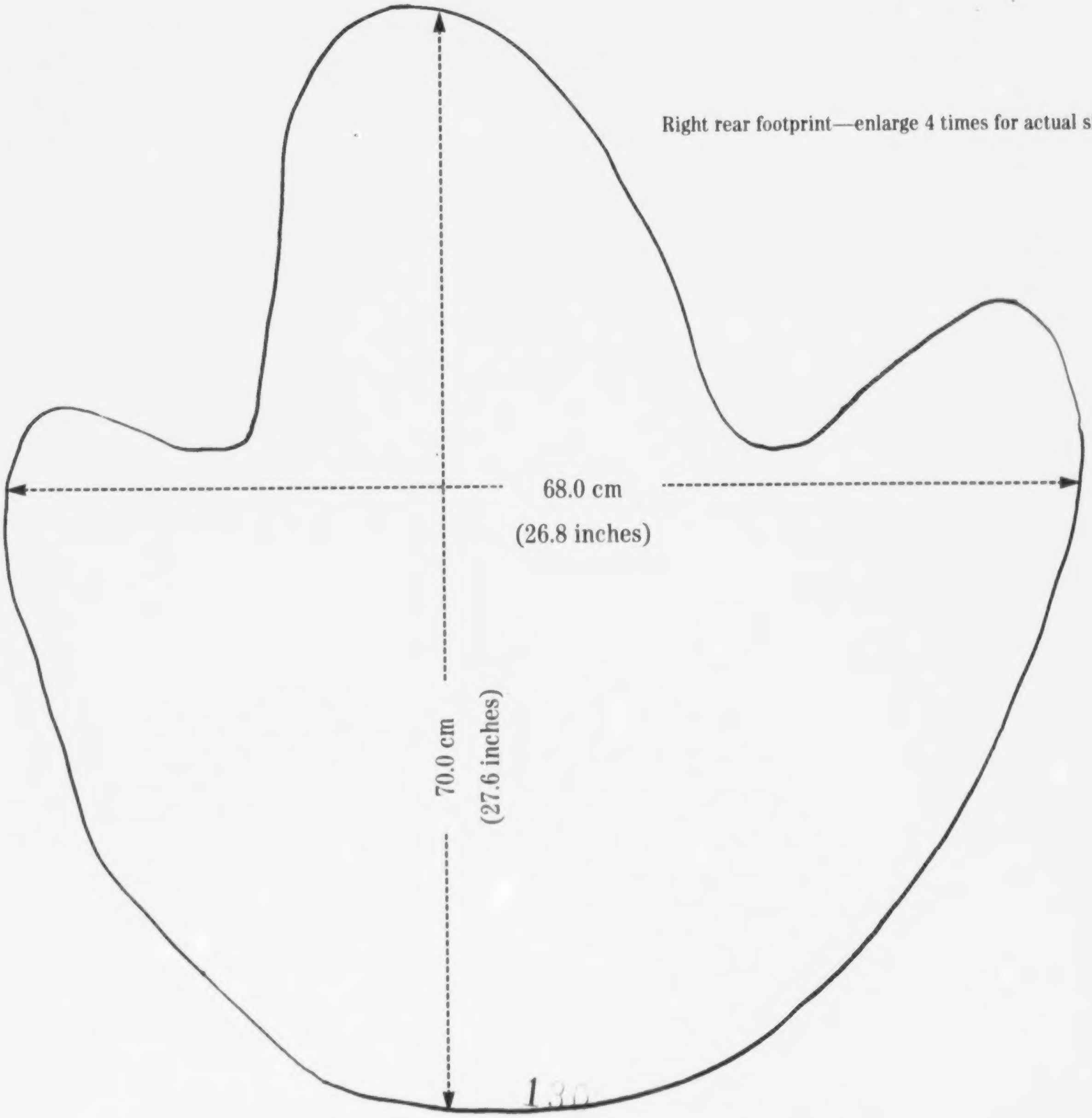
EXTENSIONS

- To make this more challenging, have your students measure their footprints in inches or centimeters. Then have them calculate the actual length and width of the *Edmontosaurus* footprint.
- You may do this activity with any other dinosaur footprints.
- You can also compare dinosaur teeth to students' teeth, handprints, and so forth.
- Visit *Dinosaur Ridge* and see some real dinosaur footprints! To find out how to get there, turn to the Colorado Connections section of this Sourcebook on page 163.

EDMONTOSAURUS FOOTPRINT



Right rear footprint—enlarge 4 times for actual size.


68.0 cm
(26.8 inches)
70.0 cm
(27.6 inches)

PRE-VISIT ACTIVITY

MONSTER MATH

MATERIALS

Animal Overhead Sheets
Cardboard
Cellophane tape
Overhead projector
Long extension cord
Rolling cart
Meter stick or measuring tape
Photocopy machine
Transparency overhead sheets

PREPARATION

Photocopy each of the Animal Overhead Sheets onto individual transparency sheets (available at most stationery stores).

Using cardboard and cellophane tape, make flaps that cover the meter line and identification name (answer) on each Overhead Sheet.

Place an overhead projector, with a long extension cord, on a rolling cart so that it may be easily wheeled around your classroom.

Practice projecting the images to correct size ahead of time. You may need a larger room.

TEACHER KEY TO ANIMAL OVERHEADS

Sheet #1: *Coelophysis*–a small, carnivorous, Triassic dinosaur.

Sheet #2: *Iguanodon*–a large, herbivorous, Cretaceous dinosaur.

Sheet #3: *Dinohyus*–a large, pig-like, carnivorous, Miocene mammal.

ACTIVITY GOALS

- To introduce students to the range of sizes among dinosaurs and other prehistoric animals.
- To help students visualize the actual sizes of these animals by projecting images in your classroom.
- To help students gain an intuitive feel for the mathematical process of scaling.

METHODS

1) Explain that prehistoric animals, including dinosaurs, came in many sizes. Today students will have the chance to guess the actual sizes of some of these animals.

2) Move the desks if necessary to make an aisle so that you can roll the overhead projector cart closer and farther from the wall. Place one of the Overhead Sheets onto the projector. Be sure that the cardboard flap is covering the answer. Project the image onto a clean, light-colored wall in your classroom.

3) As you move the projector closer and farther from the wall, changing the size of the projected image, have your students decide how big the animal actually was.

4) Once they have agreed upon a size, check their estimate by removing the flap so that the answer box is also projected onto the screen. There is a line drawn on it labeled "ONE METER." Have a student helper hold the meter stick near that line while you move the projector back and forth until the line is actually 1 meter long on your wall. At that point, the animal will also be the correct size.

DISCUSSION

Who was surprised at how little or how big some animals were?

Were all dinosaurs big?

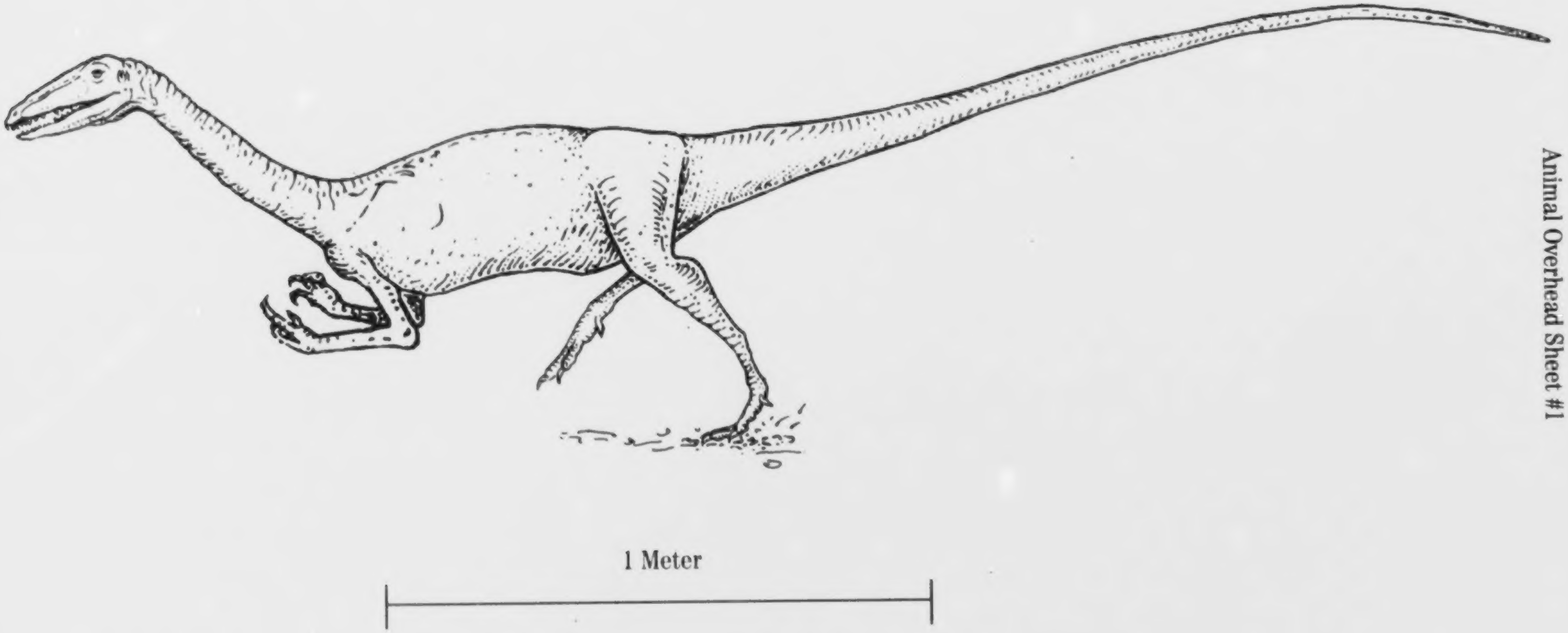
Were dinosaurs the only big animals to ever live?

TEACHER TIP

Save the largest dinosaur until last. You may not be able to fit the entire dinosaur on your wall, so try showing only part of it to actual size (maybe the leg). Every time I do this activity, kids rush up to the wall to compare themselves to the gigantic leg.

Eddie Goldstein
Math Educator,
Denver, Colorado

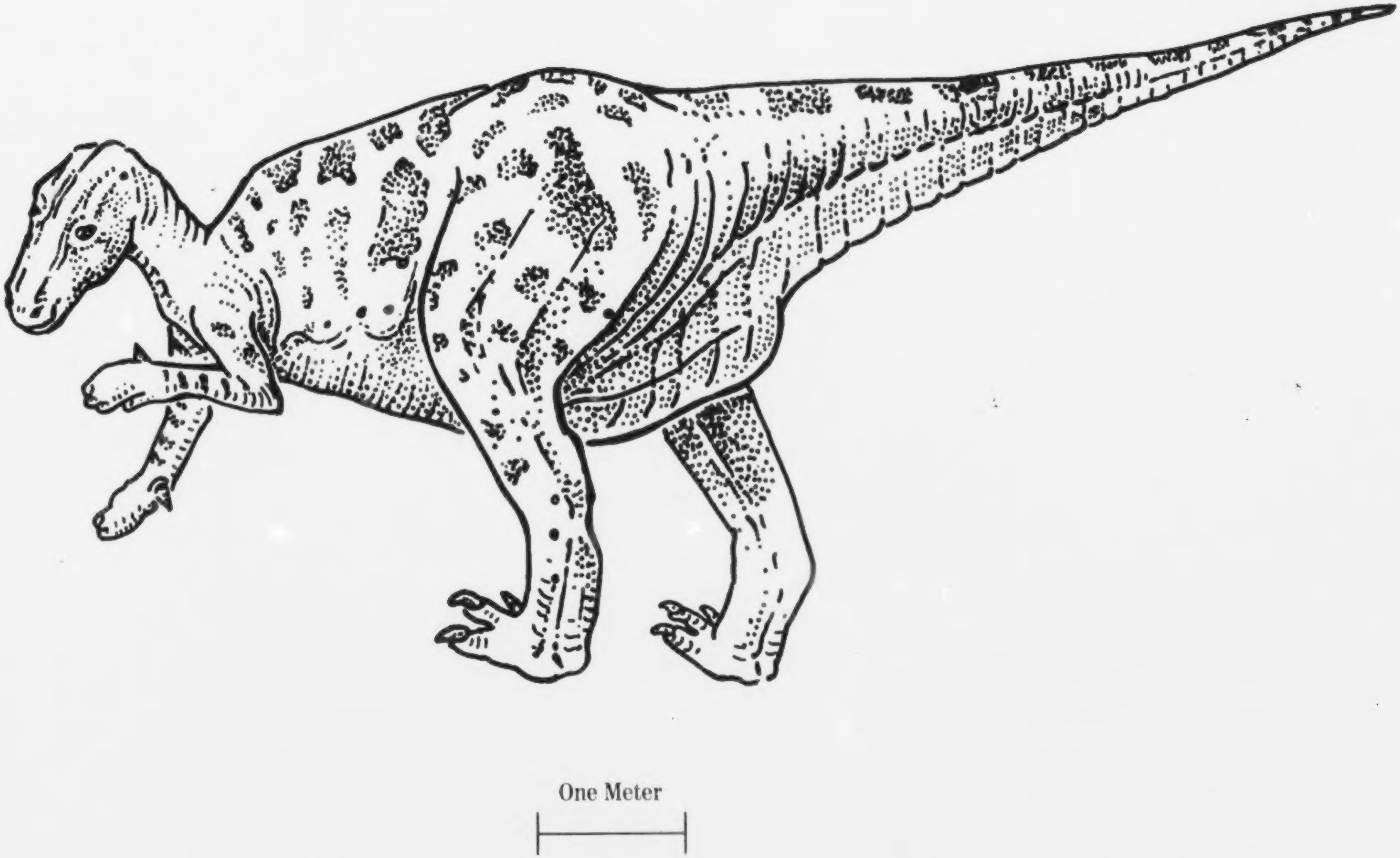
Animal Overhead Sheet #1



Coelophysis

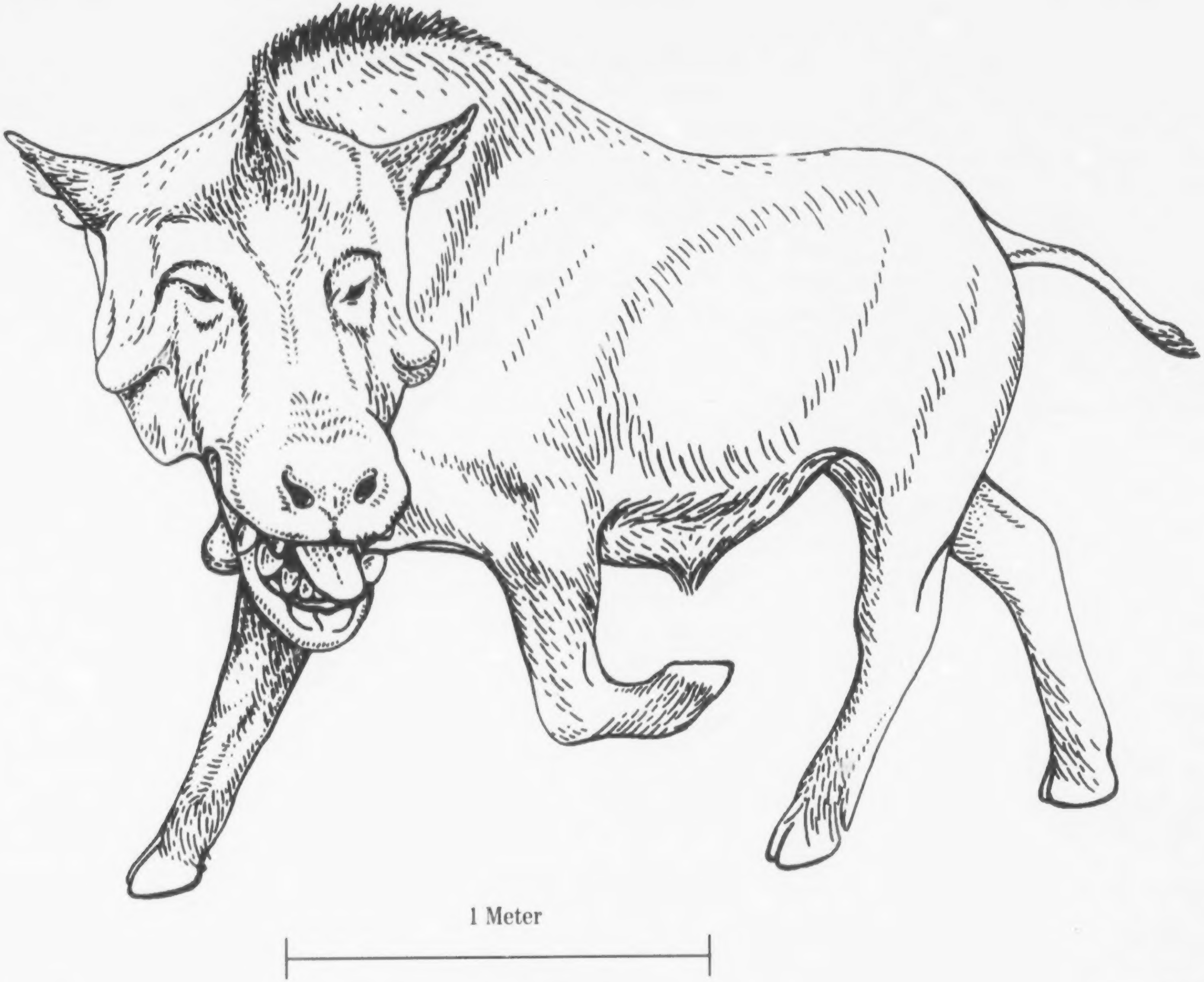
3 m (10 feet)

Animal Overhead Sheet #2



Iguanodon

10 m (33 feet)



Dinohyus

2.1 m (7 feet) high at the shoulder

Animal Overhead Sheet #3

MUSEUM ACTIVITY

SIZING UP THE PAST

MATERIALS

Sizing Up the Past
Teacher Worksheet

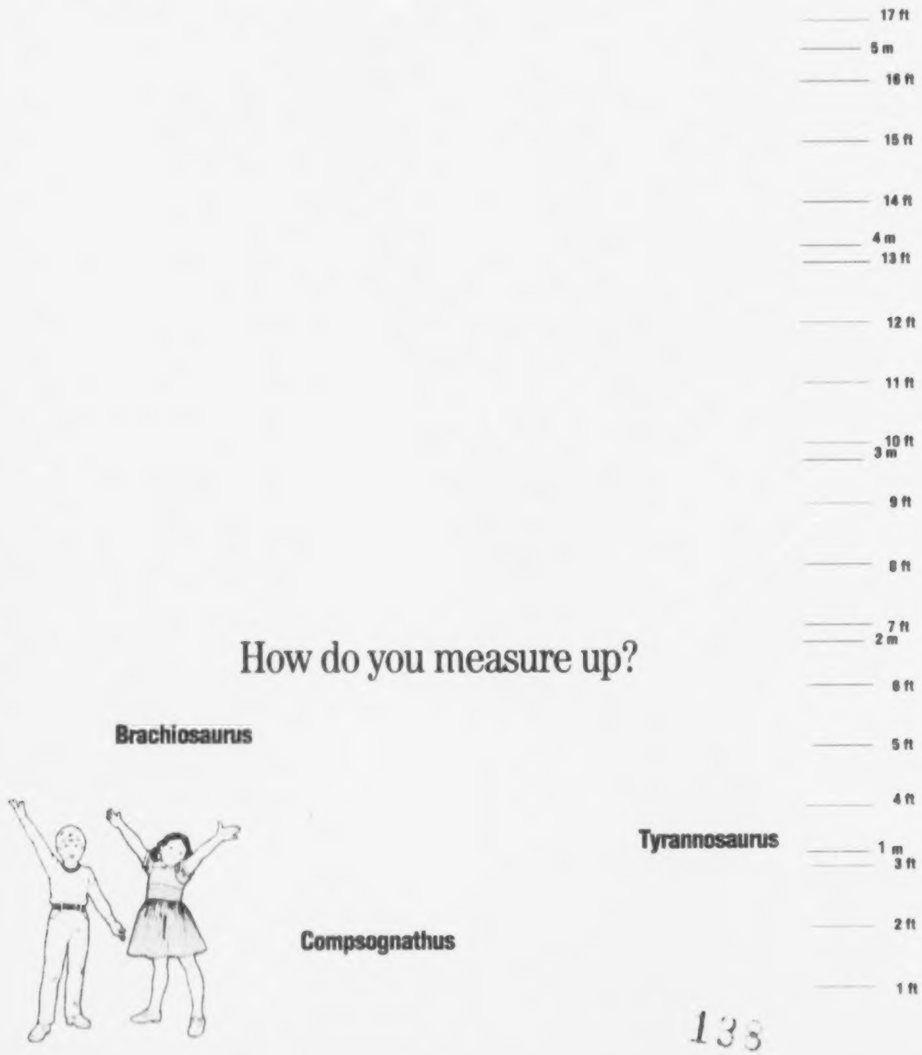
PREPARATION

Have class do the two pre-visit activities on size and scale in this Investigation Unit and review the *Time of the Dinosaurs*. .

ACTIVITY GOALS

- To allow students to focus on the diversity of sizes among prehistoric animals and plants, and discuss the environments in which different-sized organisms lived.
- To demonstrate the diversity of sizes among dinosaurs.
- To show students that every animal that is big is not necessarily a dinosaur.
- To encourage students to use their own sizes to make comparisons with prehistoric organisms.

How do you measure up?



METHODS

As you take your *Prehistoric Journey*, have your students pay attention to the different sizes of the animals and plants along the trail. Have students make the suggested comparisons on the *Sizing Up the Past* Teacher Worksheet.

DISCUSSION

What other animals or plants did you see in *Prehistoric Journey* that got really big?

What animals did you see that were really small?

What was the smallest dinosaur that you saw?

What was the biggest dinosaur that you saw?

What was the biggest animal you saw after the dinosaurs were gone?

What advantages and disadvantages are there to being a large animal? a small animal? a large leaf? a tall tree?

HOW DO YOU MEASURE UP? MURAL IN *TIME OF THE DINOSAURS* EVIDENCE AREA

How do you measure up to a *Compsognathus*, *Tyrannosaurus rex*, and a *Brachiosaurus*?

Teacher Worksheet

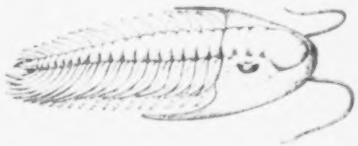
SIZING UP THE PAST

Have your students make the following size comparisons while in the exhibit and record the class results on this worksheet.

1.

How many hands **long** is this trilobite? __________

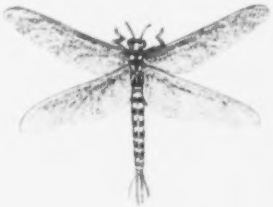
How many hands **wide** is it? __________



Bronze sculpture of giant trilobite in *Early Life* Evidence Area

2.

Is this dragonfly's wingspan **wider** than you can spread your arms? __________

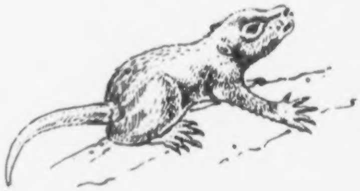


Giant dragonfly on scale tree in *Kansas Coastline* Envirorama

3.

Can you find the tiny mammal in the *Creekbed* scene?

Would it fit in your hand? __________

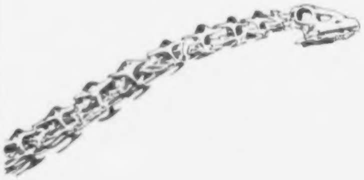


Multituberculate mammal in *Cretaceous Creekbed* envirorama

4.

How many steps **long** is this dinosaur's skeleton? (Have one student pace it off.)

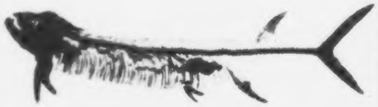
number of paces: __________________



***Diplodocus longus* skeleton in the *Time of the Dinosaurs* Evidence Area**

5.

How many students **long** is this giant fish if you stand side-by-side? __________

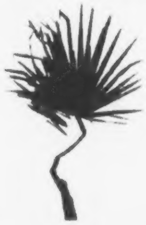


Giant *Xiphactinus* fish skeleton in the *Time of the Dinosaurs* Evidence Area

6.

Compare your **height** to this giant palm frond. Is it taller than you? __________

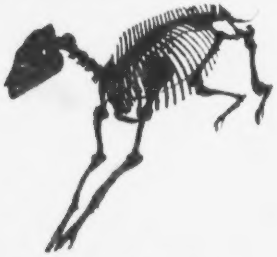
What if you stretch your arms over your head? __________________



The giant palm frond in the *Tropical Rockies* Evidence Area

7.

Compare your **height** to the early horse. How does it compare in **height** to horses you have seen? __________________



The small *Mesohippus* in the *Expanding Grasslands* Evidence Area

DINOSAUR SCENES

MATERIALS

- Drawing paper
- Writing paper
- Construction paper
- Aluminum foil
- Small stones
- Twigs
- Tempera paint
- Modeling clay
- Yarn
- Scraps of cloth
- Other art supplies

PREPARATION

Review your visit to *Prehistoric Journey*.

Have students share with the class what their favorite dinosaur in the exhibit was, what the largest and smallest dinosaurs in the exhibit were, and what the environments the dinosaurs lived in were like.

ACTIVITY GOAL

- To allow students to express what they have learned about size and scale and the *Time of the Dinosaurs* by creating a dinosaur envirorama (walk-through scene).

METHODS

1) As a class, turn part of your classroom into a walk-through dinosaur scene.
2) Choose a time period from the *Time of the Dinosaurs* (Triassic, Jurassic, or Cretaceous) to reconstruct. Help your students remember, from their field trip to *Prehistoric Journey*, what that time period was like (for example, there were no flowers in the Triassic or Jurassic; there was an inland sea during part of the Cretaceous; for more ideas, refer to pages 57–73 and the Bibliography of this Sourcebook).
3) Have students make the background first, using construction paper and paints to create the sky and land. Small stones, sticks, and cutouts may be used for vegetation and other landmarks.
4) Using clay or papier maché, students should create various dinosaurs of different sizes and other animals and plants from the appropriate time period. Encourage them to make them to scale with the other elements of their scene.
5) Have your students place their dinosaurs and other animals and plants into the scene. Don't forget about insects, early mammals, birds, and pterosaurs.
6) Ask your students what kind of special effects, like lighting and sound effects, they would like to add to their scene. Have them make sound effects or tape them on a cassette. What would the *Time of the Dinosaurs* have smelled like? Can they enhance their scene with smells?
7) Have students walk through the scene, imagining that they are walking through the living world of dinosaurs.
8) Invite other classes or parents to walk through the scene.

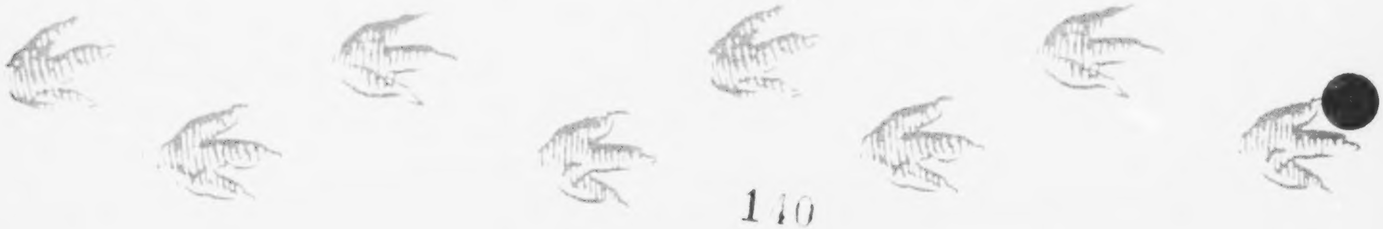
DISCUSSION

Is it hard to make your dinosaurs the right size compared to the rest of your scene?

How large were the plants during the time period you chose to reconstruct?

What types of behaviors did you represent for the animals in your reconstruction?

How would you select a fossil site to reconstruct if you were creating an envirorama for a museum?



DINOSAUR SCENES IDEAS

LATE TRIASSIC PERIOD

(Also see pages 66 and 68 in this Sourcebook.)

Animals: *Coelophysis*—small, early, carnivorous dinosaur
phytosaur—carnivorous reptile resembling a crocodile
Desmatosuchus—armored reptile

Plants: giant horsetails, ferns, cycads, gingkos, conifers

LATE JURASSIC PERIOD

(Also see pages 67 and 68 in this Sourcebook.)

Animals: *Allosaurus*—carnivorous dinosaur
Stegosaurus—herbivorous dinosaur
Othnielia—herbivorous dinosaur
Brachiosaurus—huge herbivorous dinosaur
Archaeopteryx—early bird
Docodon—small, early mammal

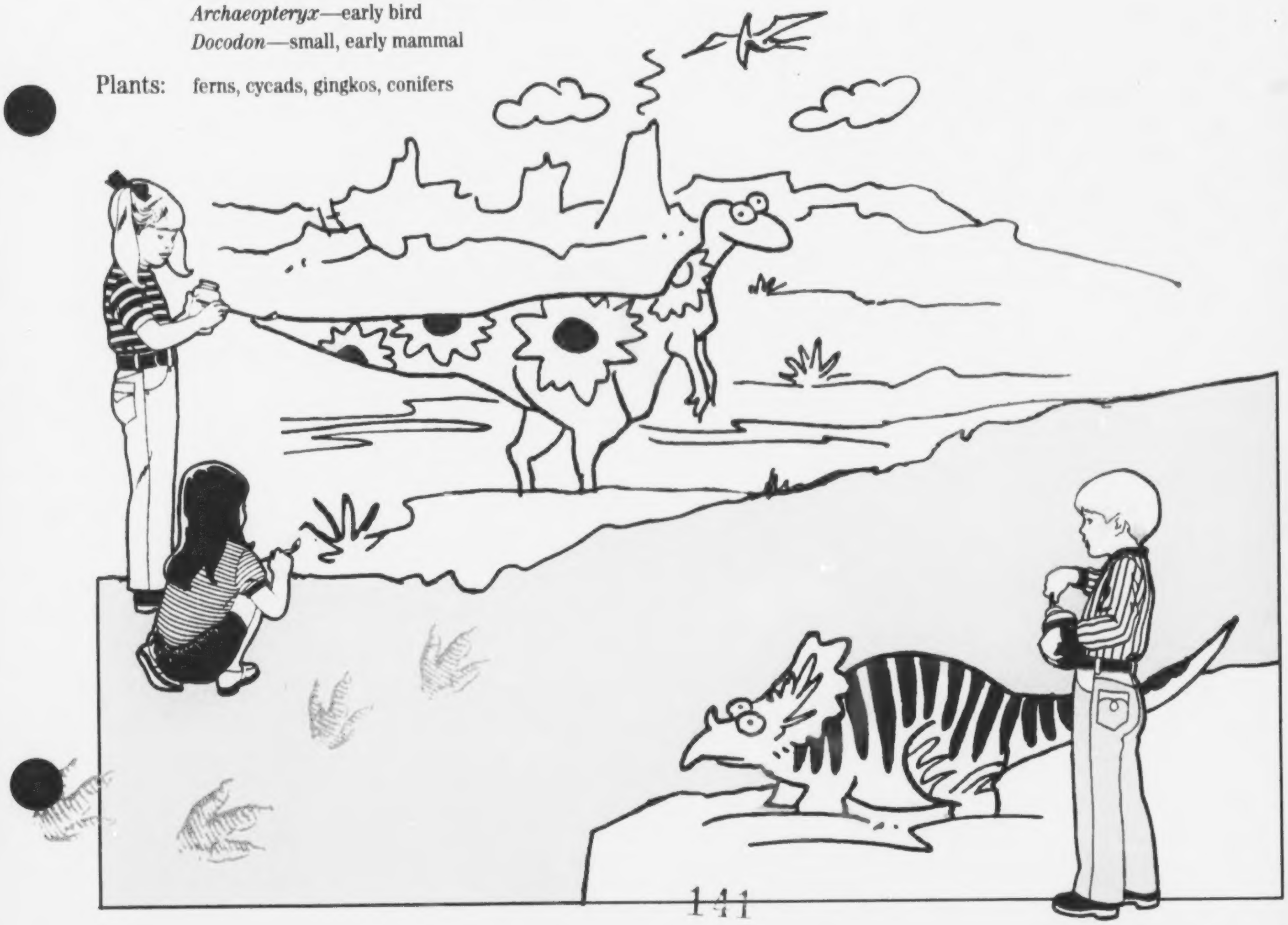
Plants: ferns, cycads, gingkos, conifers

LATE CRETACEOUS PERIOD

(Also see pages 60–61, 69, and 70–73 in this Sourcebook.)

Animals: *Stygimoloch*—bony-headed dinosaur
Didelphodon—early marsupial
multituberculate—early mammal
turtle
Tyrannosaurus rex—huge, carnivorous dinosaur
Edmontosaurus—duckbilled dinosaur
ankylosaur—armored dinosaur
Maiasaura—duckbilled dinosaur

Plants: ferns, cycads, gingkos, conifers,
sycamores, magnolias, other flowering plants



ADDITIONAL DINOSAUR ACTIVITIES

DISCOVER A DINOSAUR

1) Have the students imagine that they're paleontologists and are out digging for dinosaurs, and they have just discovered fossil dinosaur bones that have never been found before.
2) Have them answer the following questions: What did the dinosaur look like? How big was it? What did it eat? What was its environment like? And, as the discoverer of the new find, what would you name it?
3) Have the students draw their own discovery, labeling it with its new name.
4) Have the students write about their discovery.

TEACHER TIP

I always glue their stories to the back of their drawings, date, and then laminate them. This is a good way to preserve something for them to keep.

Jean Berres
First Grade Teacher,
Fairmount Elementary School

LEARN THE LENGTHS OF DINOSAURS

Cut string or strips of paper as long as different dinosaurs. For example, *Diplodocus* was 90 feet long, so cut 90 1-foot strips of paper and lay them end to end. Every 10 feet, vary the paper colors. Have the children lie next to the strips.

How many children make 90 feet?

Practice counting by tens.

BE A DINOSAUR POET

1) Make a list of your classroom's favorite dinosaurs—try to include some of the specific dinosaurs they will see in the *Prehistoric Journey* exhibit.
2) Brainstorm a list of words that describe dinosaurs.
3) Brainstorm a list of prepositional phrases telling where dinosaurs can be found.
4) Brainstorm a list of verbs that describe what dinosaurs can do.
5) Let children write their own dinosaur poem using words from the word lists and using the suggested poem format.
6) This poem can be made into a book form and illustrated. The more able student may completely make up his or her own poem. Students could also pick out one or two of their favorite dinosaurs from *Prehistoric Journey* and write a poem about that.

A variation on the poem could be a Dino Tongue Twister. For example, "Terrible-tempered *Tyrannosaurus* tears *Triceratops* into tough tidbits." Students could include tongue twisters in their book and also try them out with each other.

SUGGESTED POEM FORMAT

I like ______________________
(child's choice)
______________________ dinosaurs.
______________________ dinosaurs.
______________________ dinosaurs.
______________________ dinosaurs.
I like dinosaurs.
______________________ is my kind of dinosaur.

Dinosaurs with ______________
Dinosaurs with ______________
Dinosaurs with ______________
Dinosaurs with ______________
I like dinosaurs.
______________________ is my kind of dinosaur.

Dinosaurs in ______________
Dinosaurs in ______________
Dinosaurs in ______________
Dinosaurs in ______________
I like dinosaurs.
______________________ is my kind of dinosaur.

Allosaurus
Stegosaurus
Brachiosaurus
T-REX, too.
I like dinosaurs!
I like ______________________

DINOSAUR RAP

BY JEAN BERRES

You can't see 'em
They're long gone

You can't catch 'em
They're all gone

Dinosaurs

Lived long ago
When the earth was young
Don't you know?

Now we're first-graders and we're here to say
Dinosaurs lived long before today

Some were small and some were tall
Some you didn't know were around at all

Some were mean, some were meek
Some had a nose that looked like a beak

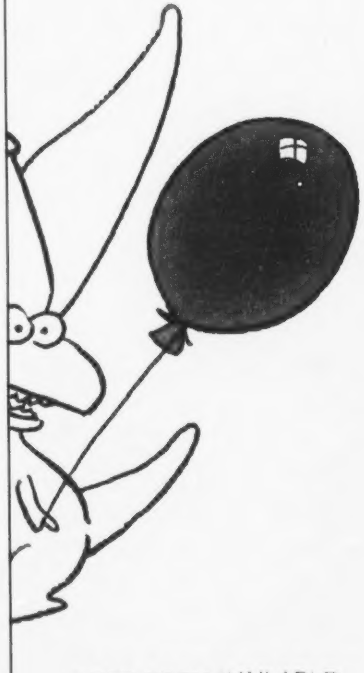
But the toughest dude that you've ever seen
Was Tyrannosaurus rex, *she was totally mean*

She was big and strong, sharp teeth and all
Now you can see her bones in a museum hall

Plant-eaters, meat-eaters, omnivores too
Some even dined on dinosaur stew

Allosaurus, Stegosaurus, Coelophysis, *too*
All dancing around, it was a dinosaur zoo!!

Dino Time!!!



BEST COPY AVAILABLE

FOSSIL LEAF LITTER

GRADE RANGE: 4–10

DURING THIS UNIT YOUR STUDENTS WILL

- Develop skills in observation, identification, and classification.
- Explore the clues and techniques paleontologists use to re-create ancient environments from fossil data.
- Be introduced to the concept of relative abundance—which trees are most abundant in a given area and why.
- Formulate hypotheses and present those views in an appropriate manner to the classroom.

Marjorie Leggitt,
scientific artist

OVERALL UNIT GOAL

To introduce students to the process of classification and identification of fossil species, and learning how paleontologists use this specific data to re-create ancient environments from fossil findings.

BACKGROUND INFORMATION

How do you re-create a 67-million-year-old forest? That's not just an idle question. *Prehistoric Journey* required realistic reconstructions of ancient trees and other vegetation, along with dinosaurs and other creatures of the time.

Fortunately, there are some clues to what Cretaceous forests looked like. Chief among these are the several fossil leaves that paleobotanist Kirk Johnson, one of the curators for *Prehistoric Journey*, found and named from North Dakota. After identifying and classifying the fossils, Johnson turned the job over to scientific artist Marjorie Leggitt. First, she created a series of highly detailed drawings of the fossils. From these, she reconstructed what the leaves probably looked like on the tree. The problem here is that most of the fossils did not include branches or even twigs, so the arrangement of the leaves wasn't always clear. But if the fossil tree in question had a modern relative (there are both fossil and modern sycamores, for instance), Leggitt examined a twig from the modern plant to see how the leaves were arranged. She was also able to see detail, such as tiny veins and blemishes, that can't be seen in the fossils but added realism to the final reconstruction.

After Leggitt had drawn the reconstructed leaves, she gave copies to foreground artist Hugh Watson. He used several techniques to construct a physical model of the leaves. One technique he used was to trace the outline of the leaf, then cut out corresponding portions of a leaf from a modern tree, and paste the cutouts onto the outline. Using this paste-up, Watson and other foreground workers and volunteers produced a final version of the leaves in plastic. Eventually, many thousands of leaves of the several extinct species were reproduced and combined with reconstructed tree trunks and branches to form the ancient forests found in the *Cretaceous Creekbed*.

®Revised from *Museum Quarterly*, 1992 Winter Issue

RELATED TOURS

GUIDED:

Ecosystems and Adaptations

How Do We Know? Advanced Ecosystems and Adaptations

SELF-GUIDED:

Earth Processes: How Do We Know?

Hugh Watson,
foreground artist

PRE-VISIT ACTIVITY

TAKE A HIKE AROUND YOUR SCHOOL

MATERIALS

Pencils
Crayons or colored pencils
Blank white paper
Comfortable clothes

PREPARATION

Choose a good area for your students to visit for a field trip (one with trees and fallen leaves). Have a discussion before going about different ways to observe leaves and how to categorize them.

ACTIVITY GOAL

To collect, observe, and classify leaves.

METHODS

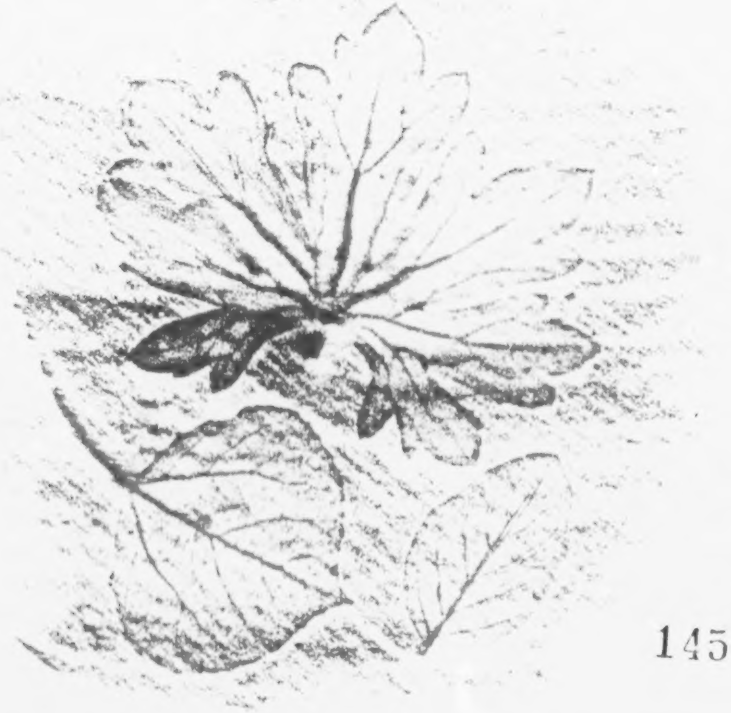
1) Take students on a hike around their school yard, or other field trip site, and observe the different leaves, branches, patterns, and bark textures that are present.
2) Have students collect two or three fallen leaves from the school yard or home and bring back to the classroom.
3) Ask students to draw, trace, or make leaf rubbings of the leaves with crayons.
4) Discuss the differences in shape, vein structure, and edges of leaves.
5) Classify the leaves according to their characteristics.

DISCUSSION

1) How are the leaves you picked similar to each other? How are they different?
2) What characteristics did you use to classify them?

EXTENTION

Have your students visit several different field sites and start a field notebook with their leaf drawings. (See page 152 in this Sourcebook for field notebook ideas.)



PRE-VISIT ACTIVITY

LEAF COUNT

MATERIALS

Copies of three Fossil Leaf pages

Lawn bags filled with randomly selected leaves for each group

Copies of the Leaf Count Worksheet for students

Pencil and paper

Copies of three Teacher Key pages

PREPARATION

Photocopy the Fossil Leaf pages several times—varying the amount of the three leaf types you give each group of three–four students. Keep track of how many leaves from the three types you give each group. Then cut them into squares and place in a lawn bag for each group.

Copy the Teacher Key pages and show them to students *after* they do this activity.

Make photocopies of the Leaf Count Worksheet for students.

ACTIVITY GOALS

- Observe and classify illustrations of fossil leaves from the *Cretaceous Creekbed* in *Prehistoric Journey*.
- Compare partial and whole leaves to determine appropriate classification.
- Determine relative abundance of fossil leaves.
- Learn about actual fossil leaves found and named by Dr. Kirk Johnson, one of the curators for *Prehistoric Journey*.

METHODS

1) Give each group of three to four students a large work area and distribute the lawn bags.
2) Ask students to look carefully at each leaf and decide which are the same and which are different and sort them into stacks. Allow 5 to 10 minutes.
3) At first your students may come up with many different types—you might want to hint that there are three different types at this time. Then have them sort out those three species and put all the leaves into three piles.
4) Ask students to count how many of each leaf type there are in each stack. Now pass out the Leaf Count Worksheet. Have students describe on the worksheet which markings or characteristics they used to determine the number of species in their lawn bags.
5) Have students draw each leaf type on the worksheet. Then on separate pieces of paper, have them draw what they think the three leaf species looked like on a branch.
6) Ask the class to share their branch drawings and compare the findings of each group to determine the total number of species of trees. It may be helpful to go over the leaves individually, discussing the characteristics and markings of each.
7) Show the class the Teacher Key of the three whole leaves and branch arrangements.

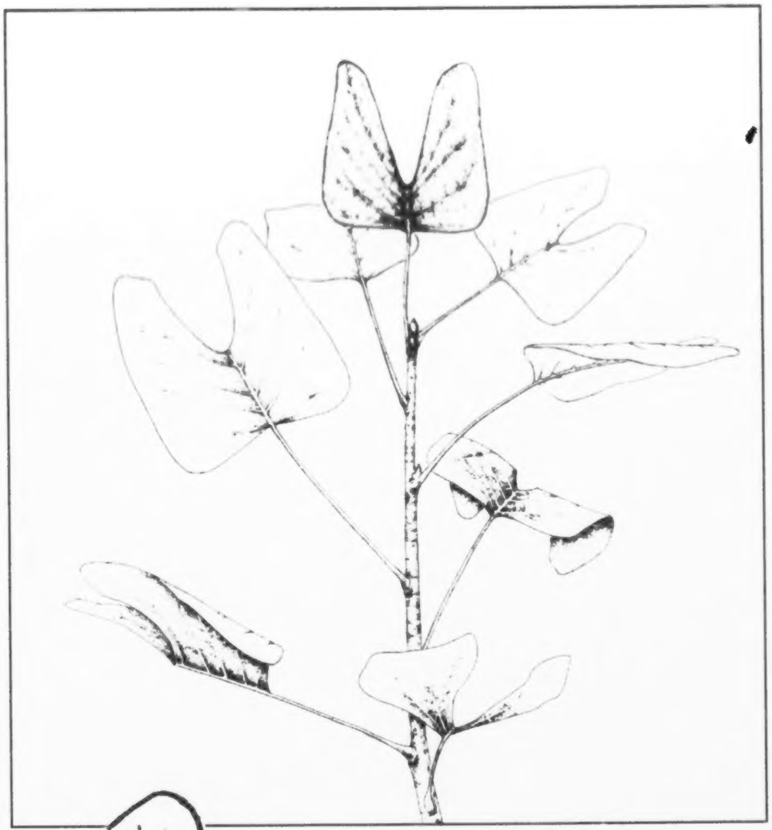
DISCUSSION

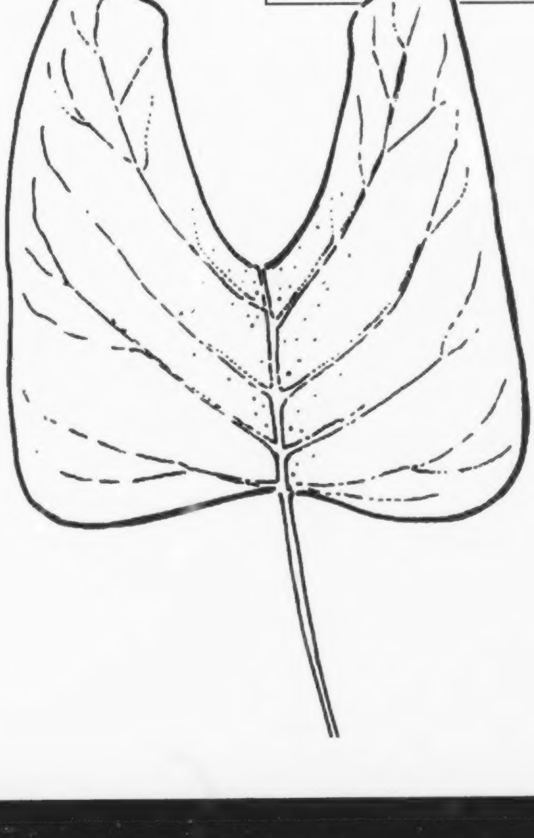
1) Discuss how the students classified the partial fossil leaves.
2) Do you think most ancient leaves were fossilized while still on the tree or after falling and becoming leaf litter?

EXTENSION

To make this activity more challenging, students can make a bar graph to determine the relative abundance of the leaves. During your classroom discussion, list what factors could contribute to abundance or lack of abundance, like climate, moisture, location, and so forth.

TEACHER KEY: Fossil Leaf #1





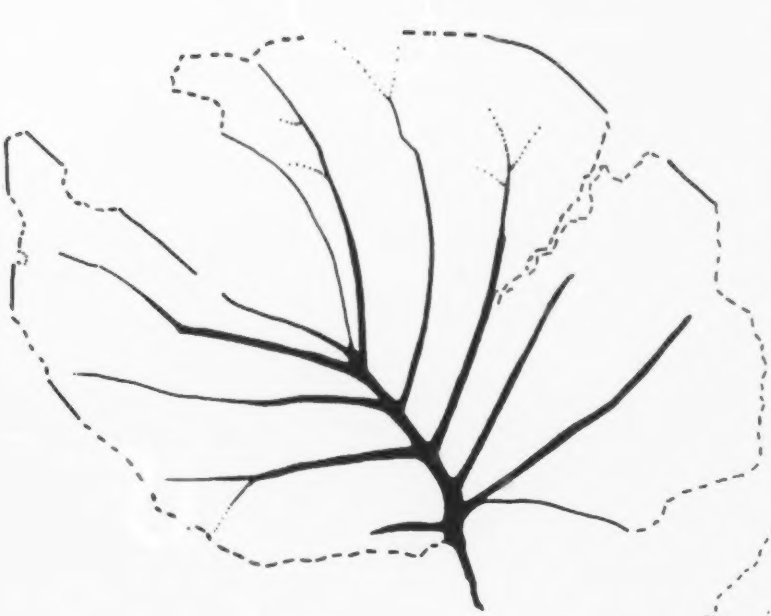
Liriodendrites bradacii

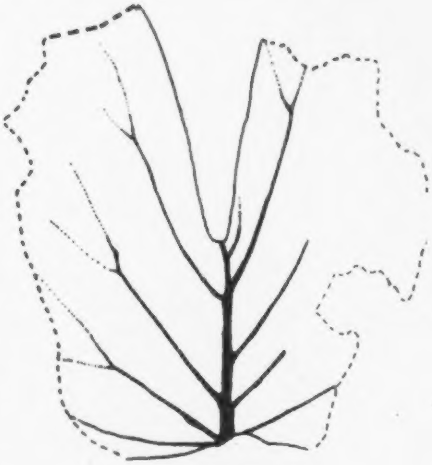
Relative of the Magnolia Family

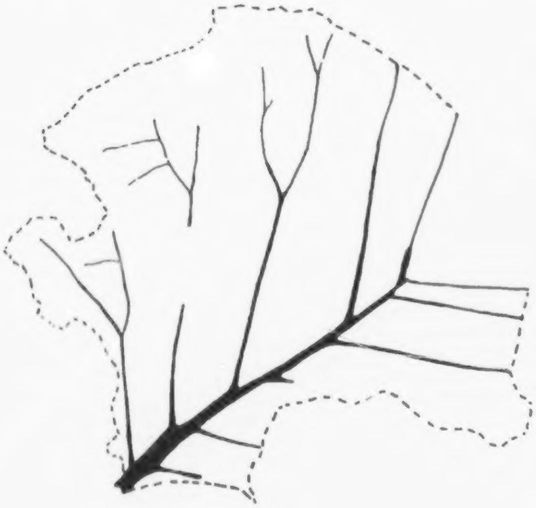
The genus name is a reference to the similarity of this leaf type and the modern *Liriodendron*, a plant in the Magnolia family.

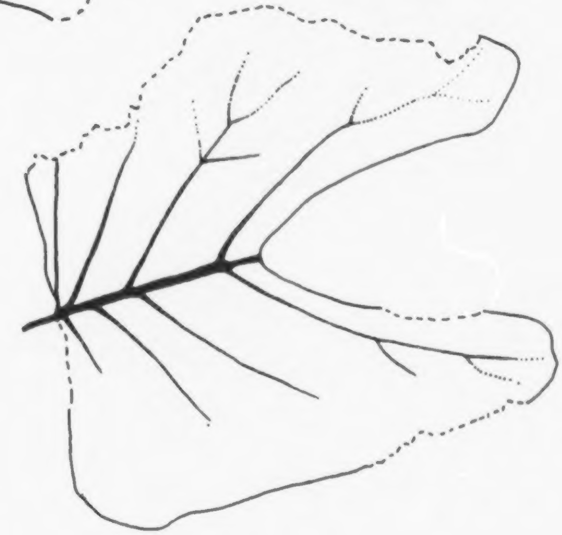
The species is named after North Dakota ranchers Henry and Scott Bradac, who have generously allowed land access to Museum scientists for many years.

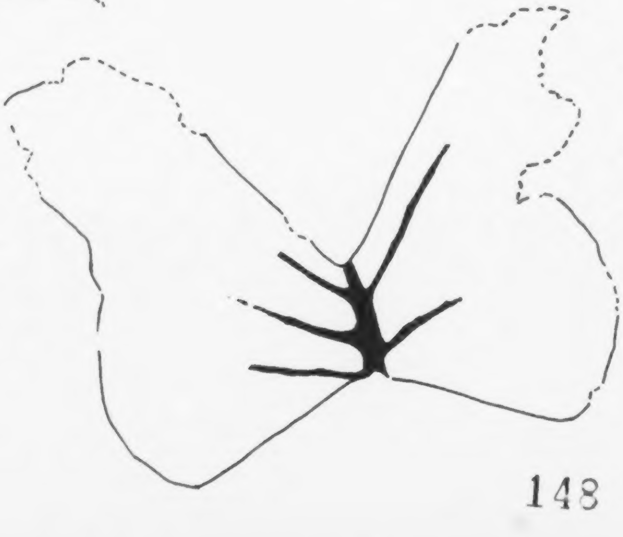
Fossil Leaf #1

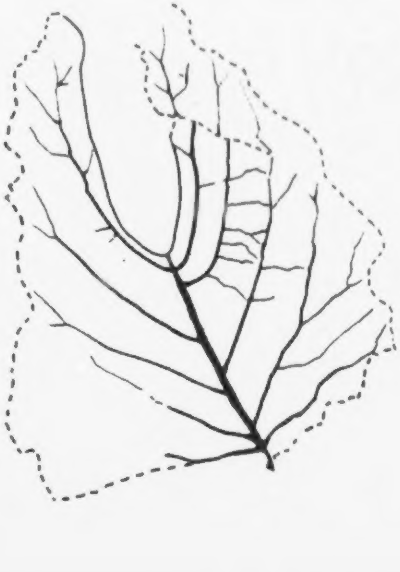




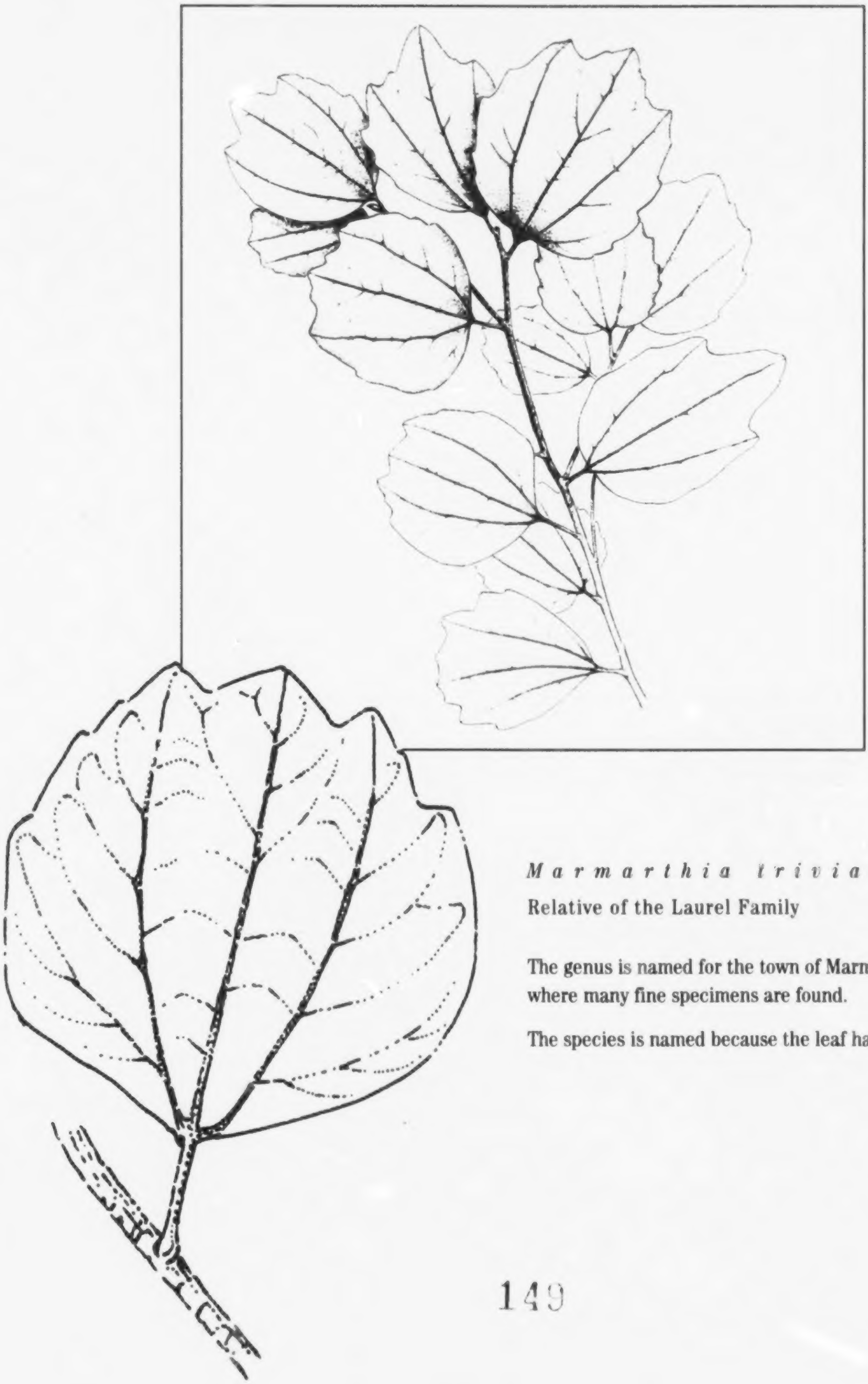








TEACHER KEY: Fossil Leaf #2



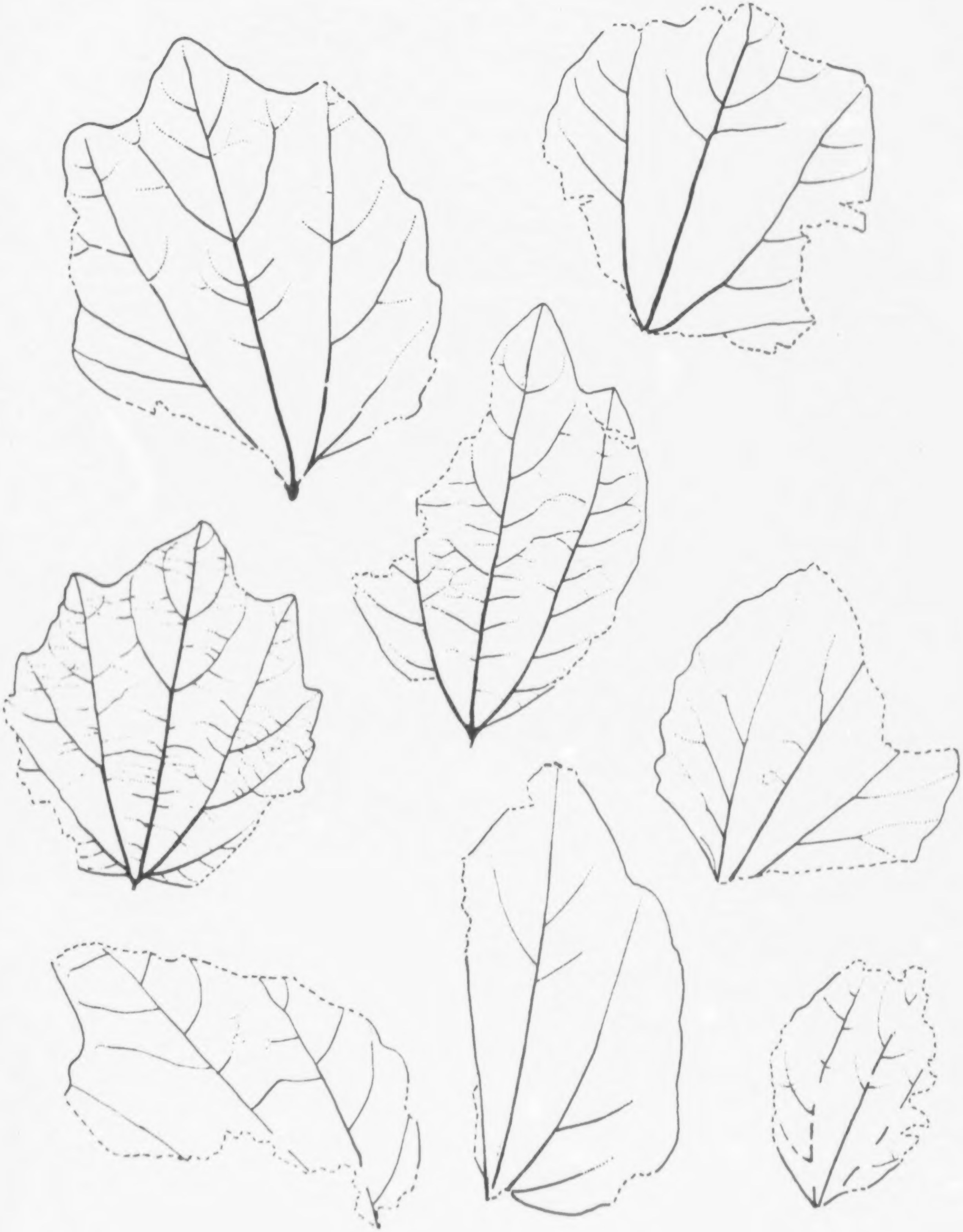
Marmarthia trivialis

Relative of the Laurel Family

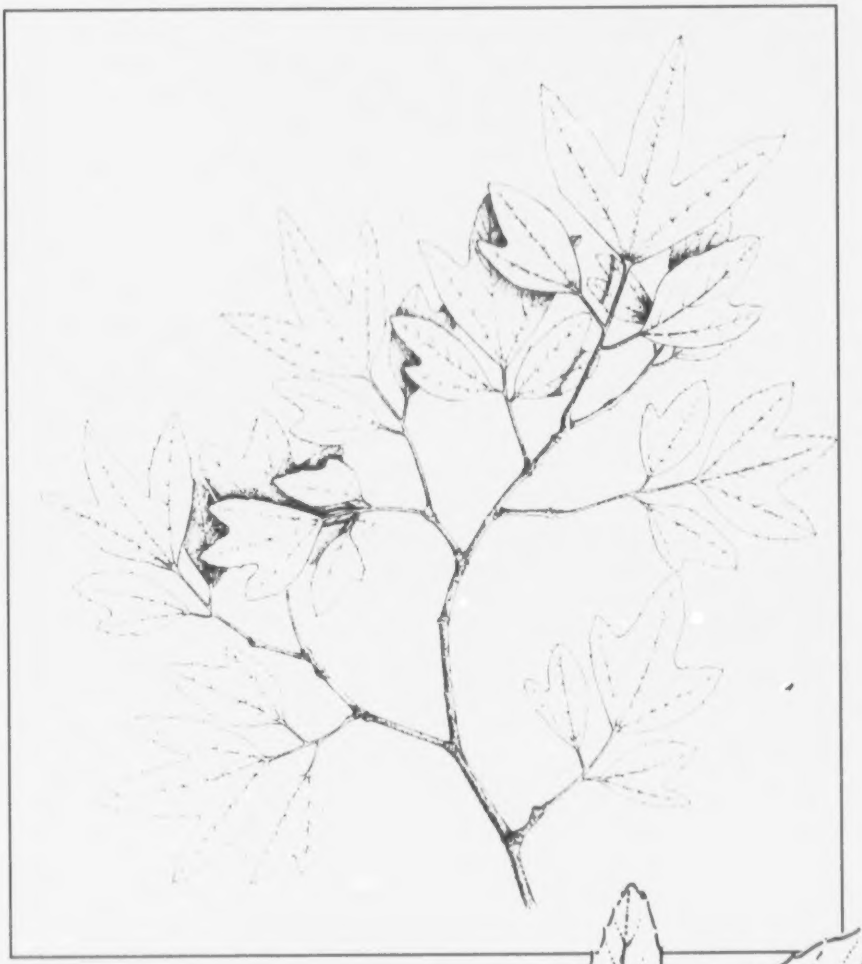
The genus is named for the town of Marmarth, North Dakota, where many fine specimens are found.

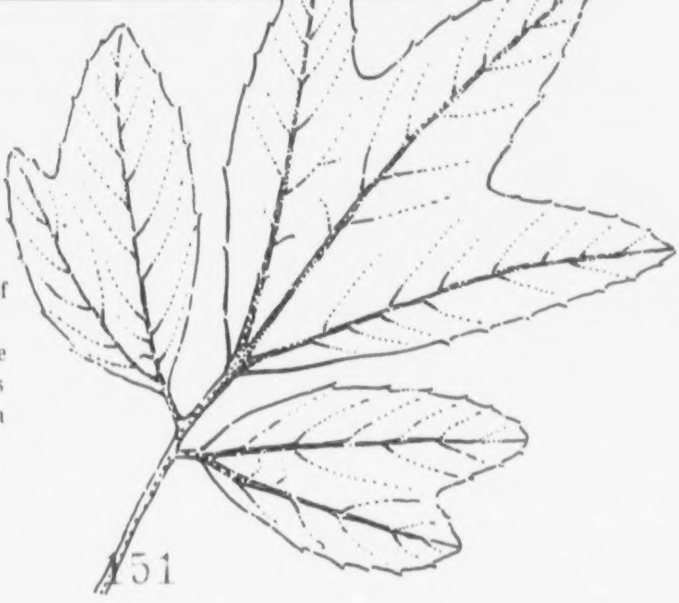
The species is named because the leaf has three primary veins.

Fossil Leaf #2



TEACHER KEY: Fossil Leaf #3





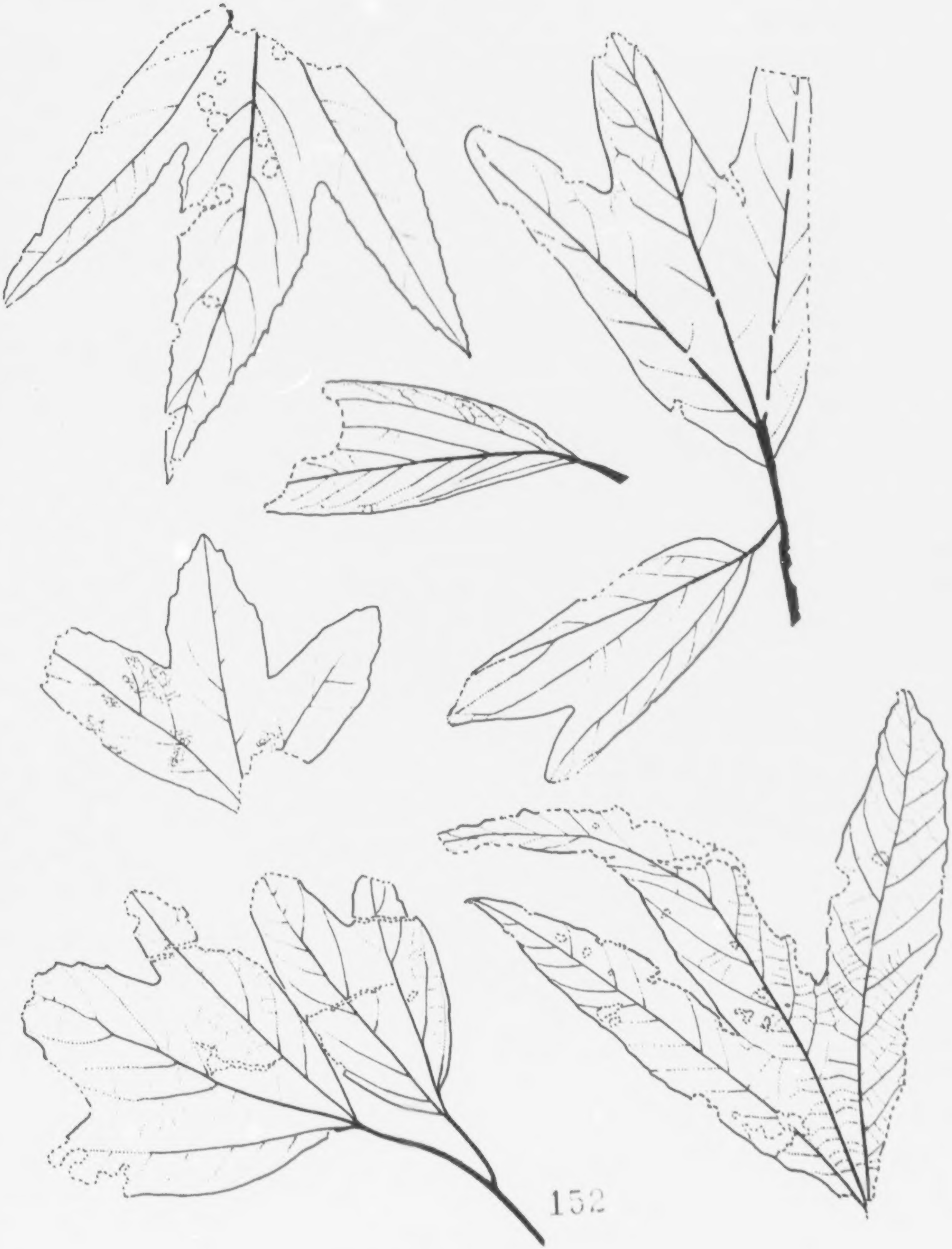
Erlingdorfia montana

Relative of the Modern Sycamores

Erling Dorf was a professor at Princeton who studied Late Cretaceous plant fossils in the 1930s and 1940s. He also discovered the fossils at Beartooth Butte (site of the *Between Two Worlds* diorama; see page 42 of this Sourcebook). "I worked with him in Montana just before his death in 1986, and the genus name is in honor of his contributions and my respect for him." Dr. Kirk Johnson

The species name was applied because the species was originally found in Montana.

Fossil Leaf #3



CRETACEOUS CREEKBED LEAF COUNT
WORKSHEET

	NAME LEAF 1	NAME LEAF 2	NAME LEAF 3
DESCRIBE THE THREE LEAF SHAPES.			
What shape are the leaves?			
What is the vein structure like?			
Describe the edges of the leaves (smooth, ragged, and so forth).			
Any other unusual leaf markings?			
How abundant is each type of leaf (how many are there)?			
What size are they?			
DRAW THE THREE LEAF SHAPES.			

MUSEUM ACTIVITY

CLASSIFY A CREEKBED

MATERIALS

Pencil and paper

Teacher Key of three branches and leaves

PREPARATION

Spend some time going over the two pre-visit activities with the class and have them look once again at the Teacher Key pages of the three leaf species.

ACTIVITY GOAL

- To use observation and classification skills to compare classroom findings with fieldwork discoveries.
- To view actual scientifically reconstructed ancient environments.

METHODS

1) During the tour of *Prehistoric Journey*, students will spend a few minutes in the *Cretaceous Creekbed* observing the different types of leaves and trees.

2) Students will pick out the tree species they learned about in the classroom.

3) They will record field notes about the following:
   - approximately how many other species of trees are represented in the *Creekbed* scene (foregrounds and mural);
   - the abundance in the *Creekbed* scene (foregrounds and mural) of the three tree species they studied;
   - and the type of climate (temperature, moisture level, and so forth) in the *Creekbed* scene.

DISCUSSION

What clues from fossil leaves might scientists use to determine what the whole tree might have looked like?

Based on your observations and notes, what do you think the climate was like during Late Cretaceous?

How many hand-made leaves do you think there are in the *Cretaceous Creekbed* scene? (Answer: *about 40,000 leaves)*

POST VISIT ACTIVITY

LEAVING LEAVES

MATERIALS

Pencils and paper
Leaf Count Worksheet
Field Notes
Forest field guides (optional)

PREPARATION

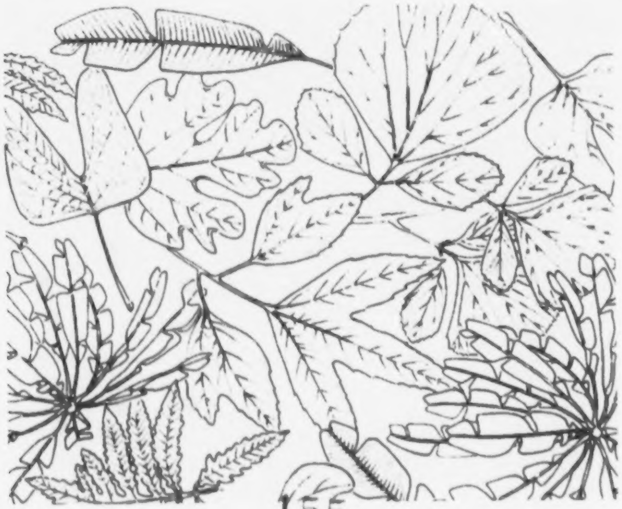
Have a review about what the students observed while visiting *Prehistoric Journey's Cretaceous Creekbed*.

ACTIVITY GOAL

- To discuss classroom and field trip findings and to present them in an appropriate manner.

METHODS AND DISCUSSION

1) Have students discuss their field notes and the following questions:
    a. What characteristics did you use to determine similarities and differences? (leaf markings, vein patterns, branches, twigs or trunks)
    b. What difficulties might scientists encounter when using fossils of partial leaves?
    c. How do scientists use fossils to re-create ancient trees? What other information do you think they use?
    d. Do you see similarities with these fossil leaves and modern leaves? (Consult field guides.)
    e. How do you think paleontologists use this kind of information to piece together ancient environments?
    f. Based on modern forests, what kind of climate and how much moisture and light do you think these trees would need to survive?
2) Assign students into groups and have them present their findings in a paper or class presentation.
3) Tell students to incorporate and organize their field notes, findings and sketches into their field notebooks and then hand them in.



EXTENSION

Paleontologists must determine the relative abundance of trees in an ancient forest by making a leaf count of the fossil leaf litter left behind. How accurate would a reconstruction like this be? To determine this, some paleobotanists go to modern forests and study the leaf litter and see how to use its contents to predict the relative abundance of trees in the forest. Students could conduct this experiment in a forested area. Count the number of leaves from different trees in a given area of the forest, predict the relative abundance of trees in that same area, and then go back and count the trees to see how good your prediction was.

ADDITIONAL PLANT ACTIVITY: TROPICAL ROCKIES

GRADE RANGE: 4–10

ACTIVITY GOAL

To have students explore the ways prehistoric plants were adapted to their environments and to compare these adaptations to modern plants in your neighborhood, botanical gardens, or other Museum exhibits.

MATERIALS

Pencil and paper

Ecosystem Worksheet

PREPARATION

Limit the number of ecosystems your students visit. For example, they could observe one modern dry ecosystem and one prehistoric wet ecosystem, which ties in well to the *Rainforest Treetop* and the *Nebraska Woodland* in *Prehistoric Journey*.

Photocopy the Ecosystem Worksheet for students.

The following are suggested modern ecosystems, besides your school neighborhood, that could be visited on the same day as your Museum outing or on a different day.

a. *Explore Colorado Hall* (Mead Hall) on the third floor of the Museum.

b. The Denver Botanic Gardens.

c. *Tropical Discovery* Exhibit at the Denver Zoo.

BACKGROUND INFORMATION

During your visit to *Prehistoric Journey*, you will see many types of plants that have been reconstructed from fossils. These prehistoric plants, as well as those found in your own neighborhood, have characteristics that allow them to survive in their particular environment. In all ecosystems, plants are affected by the climate (temperature, rainfall, wind, and so forth), by the presence of competing plants, and by the animals that eat them. Plants have evolved adaptations to allow them to survive in diverse environments. Specialized spores, seeds, and pods have evolved for effective reproduction. Some have hard coverings for protection, and some have soft fruits that animals eat, thus assisting with seed dispersal. Leaf specialization includes tiny leaves with leathery surfaces to reduce water loss, large leaves that catch sunlight in dense forests, leaves shaped with "drip tips" to drain excess rainwater, and needles that enable survival in harsh weather conditions. There are flower, stem, and root specializations as well.

METHODS

1) Have students observe and record a predetermined modern ecosystem and one in *Prehistoric Journey*. They should record their observations on the Ecosystem Worksheet.

2) Have students work together in small groups, comparing the characteristics of the modern plants with the prehistoric plants.

3) Record, in the chart provided, three characteristics of two plants in each ecosystem; describe how they help the plant survive.

4) Check to be sure all of the students are recording data. You may want to guide your adult volunteers in the proper procedure so they can help students.

5) The student groups should be forming hypotheses on why the plants have certain characteristics.

6) While in *Prehistoric Journey*, stop at the *Creating Climates* panel in the *Expanding Grasslands* Evidence Area and discuss climate. Also look at the fossils and mural from the Denver International Airport in the *Tropical Rockies* Evidence Area.

7) When you are back in your classroom, have students write up their findings in an appropriate format and write a summary comparing how the prehistoric plants are adapted to their prehistoric ecosystem with how the modern plants are adapted to their modern ecosystem.

DURING THIS ACTIVITY YOUR STUDENTS WILL

- Understand that the Earth has changed over millions of years and that plants continually change along with their environments.
- Observe and compare two ecosystems, one modern and one prehistoric, using climate, location, time period, plants, and animals as indicators to be recorded on a chart.

DISCUSSION

In what ways is this prehistoric ecosystem similar to the modern Colorado ecosystem you studied?

How is it different?

What have you observed about the plants in your prehistoric site?

How are the methods paleobotanists use to study ancient environments similar to the study of the environment today?

Were you surprised about your findings?

TEACHER TIP

This is a great activity to allow students to think and formulate their own opinions. It is important for students' answers not to be judged right or wrong. They should be able to justify their own theories. If students have looked to you for the "right" answer in the past, this may take some practice. There may be some frustration on the part of the students when they find they are responsible for their answers.

Karen Sangster
Highlands Ranch Junior High

ECOSYSTEM WORKSHEET

	PREHISTORIC	MODERN
❶ List characteristics of the modern and prehistoric environments, including location, time period, climate, plants, and animals. a. What is the climate like? Are there seasonal changes?		
b. Is water available? When?		
c. Do you see any microclimates? For example, shaded areas in a dry sunny field, depressions that may fill with water to create a temporary wetland, and so forth.		
❷ Pick two plants found in this ecosystem. Draw and describe. a. What shape are the leaves?		
b. Do they appear to have extensive root systems?		
c. What structure holds the plant upright (stems, trunks, ground cover, and so forth)? d. How do the plants spread? How are seeds or spores dispersed?		
❸ Are these plants well adapted to their environments? List three characteristics of the two plants you chose that help them survive in their environment.		

SHERLOCK BONES

GRADE RANGE: 6–COLLEGE

RELATED TOURS

GUIDED:

How Do We Know?: Advanced Ecosystems and Adaptations

SELF-GUIDED:

Earth Processes: How Do We Know What We Know?

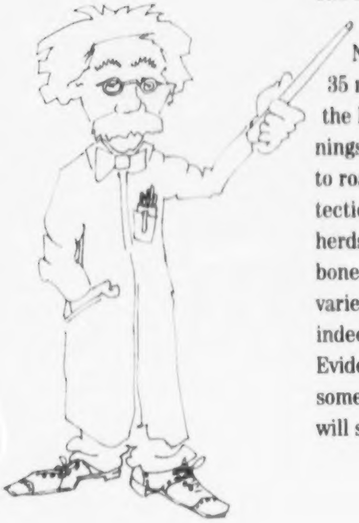
OVERALL UNIT GOAL

To use techniques of paleontology to rebuild an extinct animal from fossil clues and be introduced to the field of taphonomy.

BACKGROUND INFORMATION

Bone beds are rock layers where a large quantity of bones has accumulated and fossilized. The bones may have accumulated because all of the animals were traveling together and were killed suddenly, or the animals may have died at different times and their bones were later transported to the same place (for example, washed up on a sandbar). How do scientists figure out how each particular bone bed was formed? There is a special branch of paleontology, called taphonomy, that involves figuring out what happened to an animal at the time of death and after its death. (See the Clues Taphonomists Use page.)

Scientists can use rich fossil bone beds to determine how animals lived or cared for their young. In addition, the fossils can help paleontologists figure out what the animals looked like. Sometimes this is more difficult than it seems because the fossils are often broken and scattered. Paleontologists don't usually find an entire skeleton that is still articulated. Most of the time the scientists must figure out what the animal looked like from only a few bones. In this Investigation Unit, students will start out with just a few fossil clues, adding more as the unit progresses. It is like putting together the pieces of a puzzle. This allows them to see how an increasing amount of information can change their perspective about what an ancient animal looked like.



The mystery animal in this Investigation Unit is the extinct rhinoceros *Trigonias*. *Trigonias* lived in what is now western North America during the late Eocene Epoch (approximately 35 million years ago). Rhinos began to live and travel in herds as the landscape began to open up (less dense forests, the beginnings of open grasslands), so there was more room for the herds to roam. Moving in large numbers gave these animals some protection from predators. How do we know they were traveling in herds? From the bone beds, of course. Some extremely rich fossil bone beds preserve the bones of many rhinoceros individuals of a variety of ages and sizes, suggesting that these animals did indeed live in herds. The bone bed in the *Tropical Rockies* Evidence Area of *Prehistoric Journey* contains the remains of some *Trigonias* rhinoceroses. This is the bone bed that students will study during their visit to *Prehistoric Journey*.

DURING THIS UNIT YOUR STUDENTS WILL

- Develop skills in observation and identification of bones.
- Learn more about the fossil clues that paleontologists use to reconstruct ancient animals and environments.
- Learn how to record data and keep good field notes.
- Use data/field notes to reconstruct ancient animals and environments.
- Use writing skills to communicate ideas/theories about the extinct rhinos.

TEACHER TIP

Kids love a good mystery or getting to play detective. In this activity students become taphonomists and practice the skills of observation and scientific reasoning to reconstruct a story or event. The kids really get into solving these kinds of problems, and the opportunities for creativity abound.

Pam Schmidt
Eighth Grade Teacher,
Thunder Ridge Middle School

BEST COPY AVAILAB

CLUES TAPHONOMISTS USE

EVIDENCE	**INTERPRETATION**
Whole bones or skeletons	*Rapid burial by sediment immediately after death.*
Broken bones	*Bones were either trampled by other animals or broken before they were buried. Squashed or distorted bones may also have been deformed (underground) during fossilization.*
Rounded or abraded edges	*Bones were transported and worn down by water after the animal died.*
Tooth marks	*Indicate predation or scavenging by other animals. You can tell from the marks what kind of animal did the chewing.*
Piles of similar-sized bones	*Bones were transported by running water, which tends to sort bones by size.*
Mudstone matrix (rock) around bones	*The animal was buried quickly in a pond, lake, or floodplain.*
Different sizes of the same body parts found together	*Old and young animals lived together, probably in a herd.*

The Sherlock Bones exhibit case is in the *Expanding Grasslands* Evidence Area. You can see examples of each of these there.

PRE-VISIT ACTIVITY

MYSTERY OF PREHISTORY PART I

MATERIALS

Bone puzzles #1 and #2
Pencil
Teacher Key to bone puzzles
Field notebook
Colored pencils or markers

PREPARATION

Photocopy Bone puzzles #1 and 2 for each student group.

For your students to get the most out of this Investigation Unit, they will need to understand fossils, fossilization processes, and how paleontologists use fossils to reconstruct ancient animals and environments.

You may also want to discuss the Eocene Epoch and what North America was like during that time.

Students should receive some instruction about what kind of information should be included in a field notebook that they can make or you can give them. (See page 152.)

If your students do not have any background on bones, what they look like, and how they go together, you should spend some time on this. Using real bones and pictures of a variety of animal skeletons would be helpful.

ACTIVITY GOAL

To use a partial set of a fossil animal's bones to infer what the entire animal was like.

METHODS

1) Break students into groups of three or four and hand out the first bone puzzle. Have your students cut out the individual bone pieces and try to put them together correctly like a puzzle. Tell your students that this puzzle is of an animal from the Eocene.

   Explain that this first set includes the bones that are most often preserved in the fossil record; therefore they are the ones that paleontologists usually have to work with.

2) Suggest to students that the first step in figuring out the fossil puzzle is through observation and identification of the different bones. Allow a few minutes for this process. (Could use Bone Tally Sheet also.)

3) Now ask students to spend 10 minutes writing a description of what their animal might look like, based on the bones in the first set. Their descriptions can also include a picture of what the animal might have looked like.

4) Spend some time allowing students to share their descriptions and discuss the differences in interpretations.

5) Hand out the second bone puzzle. Again, have students cut out the bone pieces. This set includes bones that have the next highest "survival ratings." (Survival ratings are determined by how likely a particular bone will survive factors like scavengers, trampling, river transport, and abrasion to become part of the fossil record—there have been actual studies and experiments done on this.)

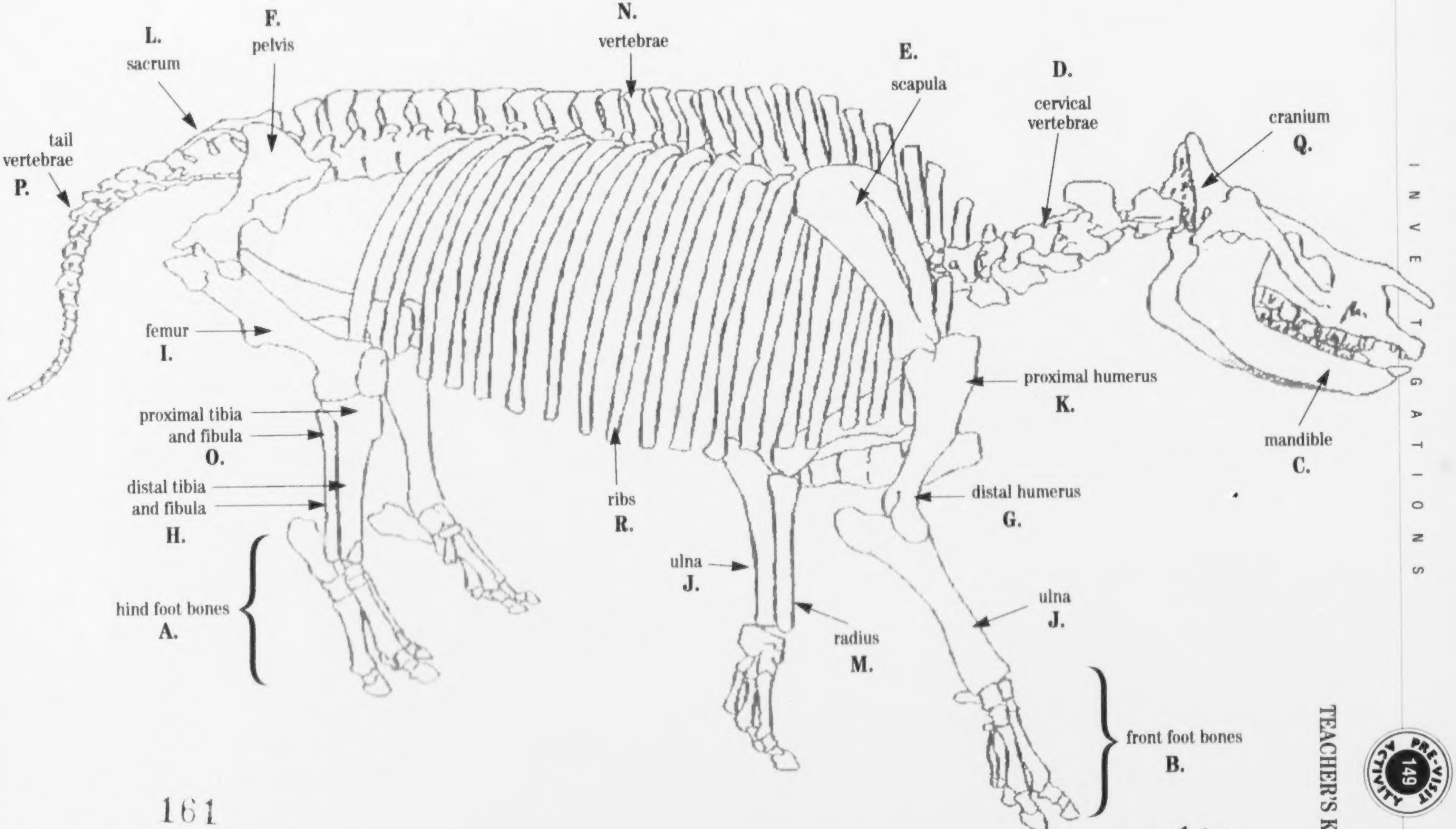
6) Repeat steps 1–3 with the second set of bones added to the first.

Important! Do not tell the students these puzzles are rhinoceroses or let the students see the completed *Trigonias* skeleton/fleshed-out page until the post-visit activity.

DISCUSSION

1. How did you figure out how to put the bones together? What clues helped you?
2. Did you think about the bones of other animals that you know?
3. How did receiving more bone puzzle pieces change your interpretation of how the animal looked?
4. How do you think your ancient animal moved? What clues gave you these ideas?

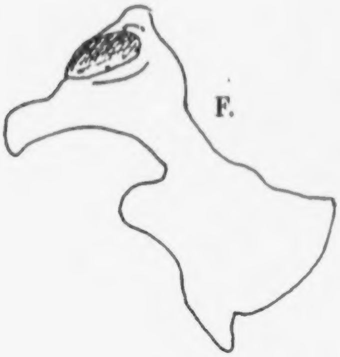
TRIGONIAS


L.
sacrum
F.
pelvis
N.
vertebrae
E.
scapula
D.
cervical vertebrae
cranium
Q.
tail vertebrae
P.
femur
I.
proximal tibia
and fibula
O.
distal tibia
and fibula
H.
hind foot bones
A.
ribs
R.
ulna
J.
radius
M.
proximal humerus
K.
mandible
C.
distal humerus
G.
ulna
J.
front foot bones
B.

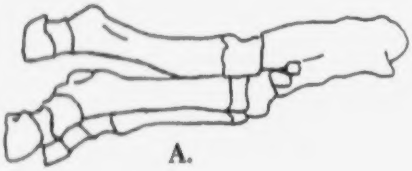
Bone Puzzle #1

MOST FREQUENTLY FOUND BONES

Identify these bones: front and hind foot bones, mandible, cervical (neck) vertebrae, scapula (shoulder blade), pelvic bone, distal (far end of) humerus, and distal (far end of) tibia and fibula.

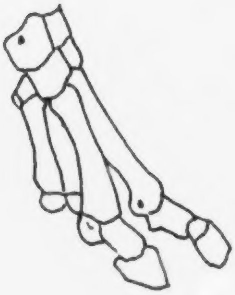


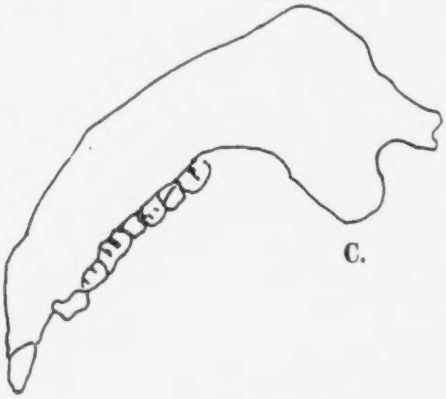
F.



A.

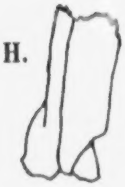
B.

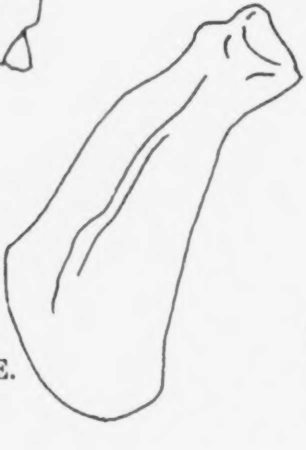




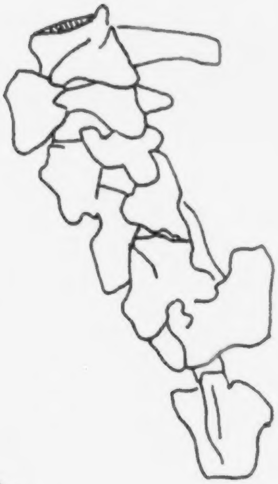
C.

H.

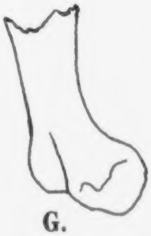




E.



D.



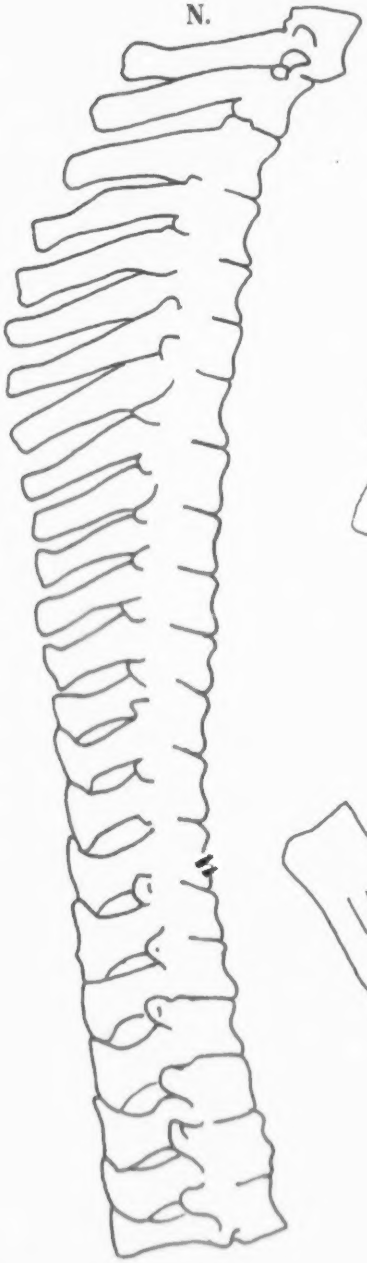
G.

Bone Puzzle #2

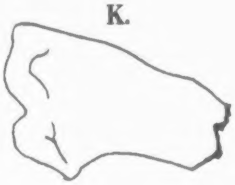
SECOND HIGHEST SURVIVAL RATING

Identify these bones: femur, ulna, proximal (end closest to body core) tibia and fibula, proximal (end closest to body core) humerus, sacrum, radius, and more vertebrae.

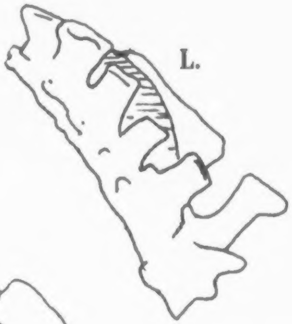
N.



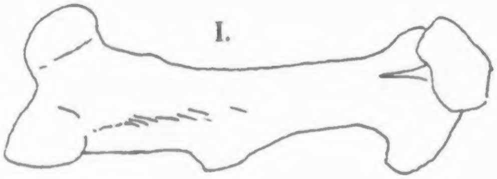
K.



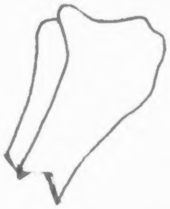
L.



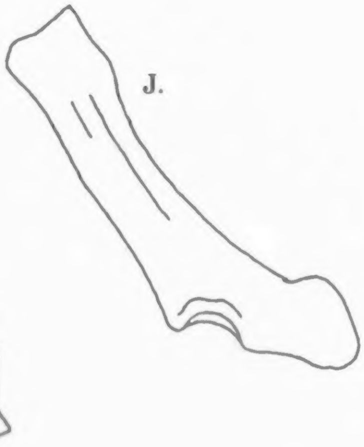
I.



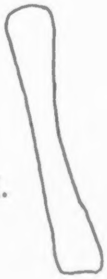
O.



J.



M.



MUSEUM ACTIVITY

VISIT AN ACTUAL BONE BED

MATERIALS

Bone Tally Sheet
Field notebooks
Pencil

PREPARATION

You may want to discuss the Eocene Epoch and what North America was like during that geologic time period before visiting *Prehistoric Journey*.

Copy the Bone Tally Sheet for each student.

Each student should prepare a field notebook.

ACTIVITY GOAL

To take a tally of the bones in a bone bed, record locality information, and speculate on the number of animals represented by the bones.

METHODS

1) Students need to bring their Bone Tally Sheet and field notebook to the exhibit.
2) Student groups should spend a few minutes at the *Trigonias* bone bed in the *Tropical Rockies* Evidence Area. They should complete the Bone Tally Sheet and make notes in their field notebooks about the "site."
3) Have students speculate how many rhinos there are in the bone bed based on their data.

DISCUSSION

Spend time discussing what you saw in the exhibit.

What are some of the different techniques you saw?

How do the scientists reconstruct actual fossils?

SITE

Tropical Rockies Evidence Area–*Trigonias* bone bed

FIELD NOTEBOOKS

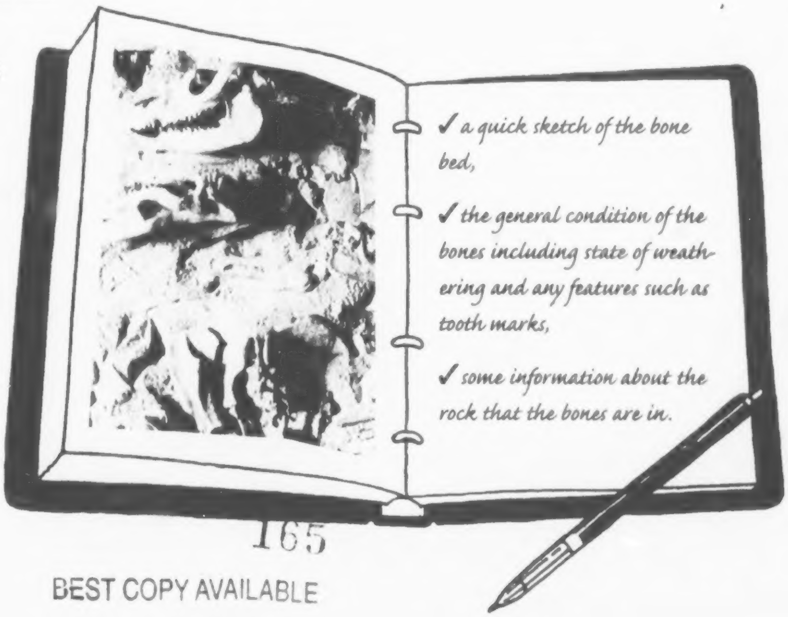
It is very important in paleontology to keep detailed and accurate field notes. A fossil without locality information is basically worthless to the paleontologist. For an actual site, information that should go into the field notebook would include the following:

1. **Locality/Stratigraphic Information** including map coordinates; type of locality (quarry, cave); collecting conditions; possible collecting biases (specimen size, equipment); stratigraphic information (formation, age); and topography.
2. **Geologic Information** including number of fossil beds; size and thickness of fossil beds; lithology (grain size, composition); sedimentary structures (cross bedding, ripple, burrows, tracks); and inferred depositional environment.
3. **Fossil Information** including position of specimens; drawings; degree of articulation; size range of bones; surface features (cracks, abrasions, tooth marks, and so forth); and number and type of bones.

Because of the time constraints while visiting *Prehistoric Journey*, students will not have time to include all of these items in their field notebooks for this activity. It is suggested that they use the Bone Tally Sheet to get a count, and include just the following information in their field notebook:

- a quick sketch of the bone bed;
- the general condition of the bones, including state of weathering and any features such as tooth marks;
- some information about the rock that the bones are in.

This should be enough information to make some general conclusions about the "site" when you get back to your classroom.


✓ a quick sketch of the bone bed,
✓ the general condition of the bones including state of weathering and any features such as tooth marks,
✓ some information about the rock that the bones are in.

BEST COPY AVAILABLE

BONE TALLY WORKSHEET

Indicate how many of each of the skeletal elements are present in the bone bed.

Skull ______

Mandible (lower jaw) ______

Vertebrae (backbones) ______

Ribs ______

Scapula (shoulder blade) ______

Pelvis (hip bones) ______

Humerus (upper front leg) ______

Femur (upper back leg) ______

Lower front leg bones ______

Lower back leg bones ______

Foot and ankle bones ______

Any other bones

______________________ ______

______________________ ______

______________________ ______

______________________ ______

Using the number of bones tallied, try to determine the number of animals whose remains are in the bone bed. Don't forget that a single rhino has more than one of some of the bones listed above.

TOTAL NUMBER OF ANIMALS ____________________

Write out your final answer, and how you decided on it.

____

____

____

____

____

POST VISIT · ACTIVITY ·

MYSTERY OF PREHISTORY PART II

MATERIALS

Bone puzzle #3
Field notebooks
Teacher Key to bone puzzles
Pencil
Colored pencils or markers
Illustration of *Trigonias* skeleton and fleshed out
Bone Tally Sheet

PREPARATION

Review what they have learned in the pre- and during-visit activities, and the *Tropical Rockies* Evidence Area.

Photocopy Bone puzzle #3 for each student group.

ACTIVITY GOAL

To complete their bone puzzles and review their field notebooks, using this information to put together a picture of how *Trigonias* looked and lived.

METHODS

1) Students should return to the same groups they had during the pre-visit activity. Give them the final set of bone puzzle pieces. Have them repeat steps 1–3 of the pre-visit activity, adding the new bones to what they already learned.
2) Have each group draw their final interpretation of what the animal looked like. Include a written description that explains how and why they reconstructed the animal the way they did. (What pieces of evidence were used?)
3) Students should explain their results to the other groups.
4) *Now* show the students pictures of *Trigonias*, both the skeleton and fleshed-out renditions.
5) Compare and contrast them to the students' ideas.
6) Now that students know the identity of the mystery animal, they should consult their field notebooks on the *Trigonias* bone bed to put together an overall picture of how *Trigonias* looked and lived.

NOTE: Consult the background information on the first page of this unit to assist you in facilitating student discussion.

DISCUSSION

1. Were they surprised about how the skeleton fit together?
2. How do you think paleontologists piece together real fossil puzzles?
3. What factors might make it easier or harder for paleontologists than it was for you with the pretend fossils?

EXTENSION ACTIVITY

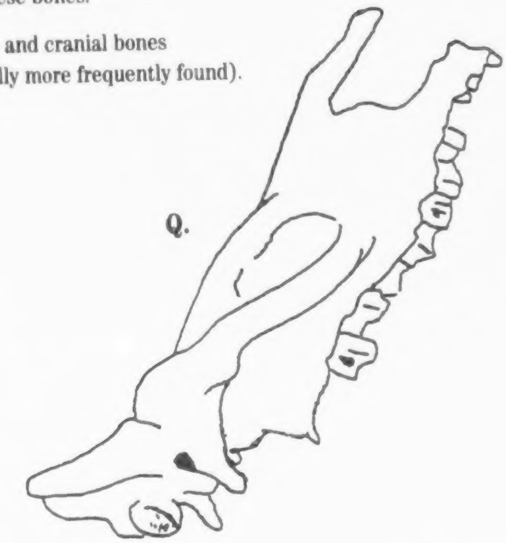
If your students have had a lot of work with bones, paleontology, or taphonomy, or if they just seem to pick up on this material quickly, there's more that you can do! In the *Expanding Grasslands* Evidence Area, there is another bone bed. This one is composed of the bones of smaller rhinos, *Menoceras*, and is much more complicated to interpret.

Bone Puzzle #3

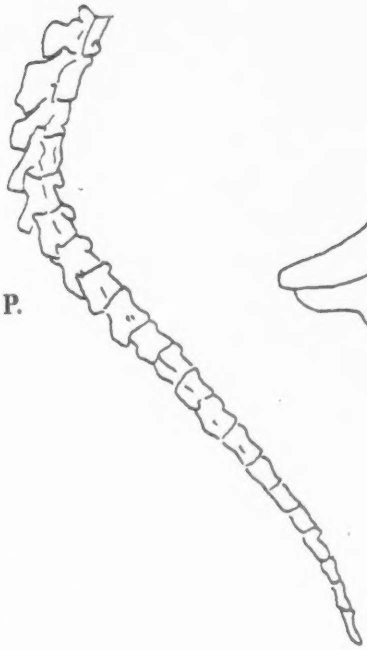
LEAST FREQUENTLY FOUND BONES

Identify these bones:

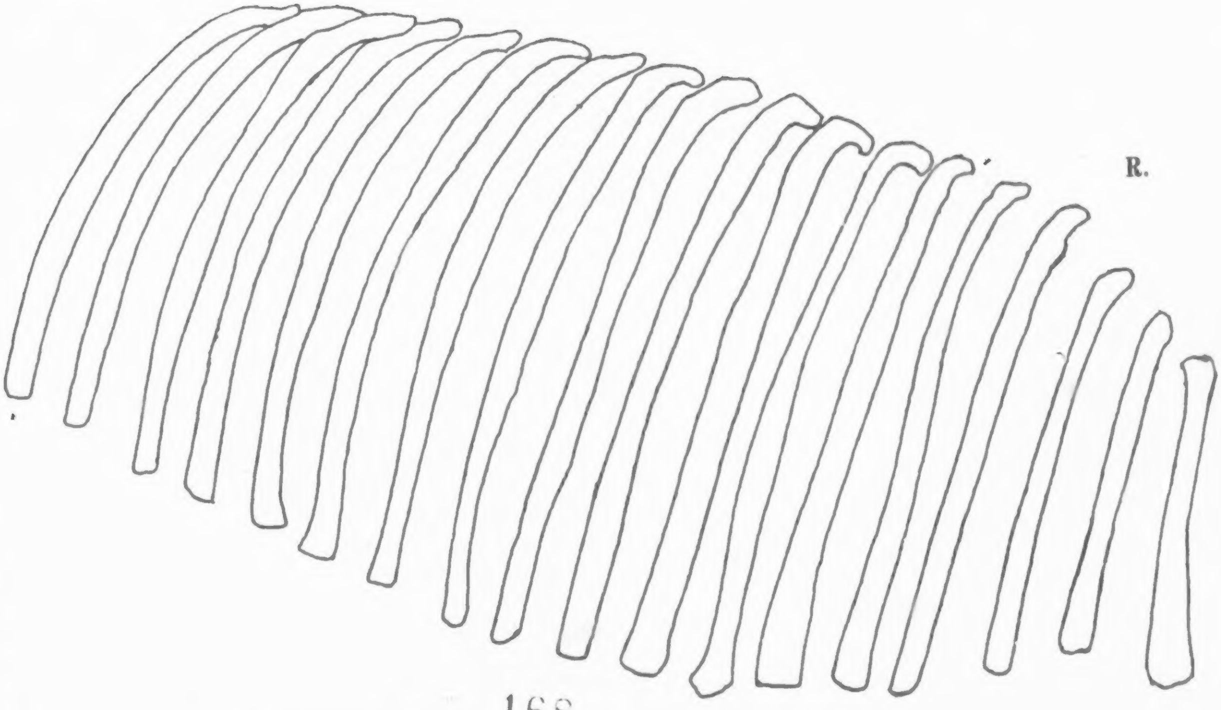
ribs, tail vertebrae, and cranial bones
(teeth are harder and usually more frequently found).



Q.



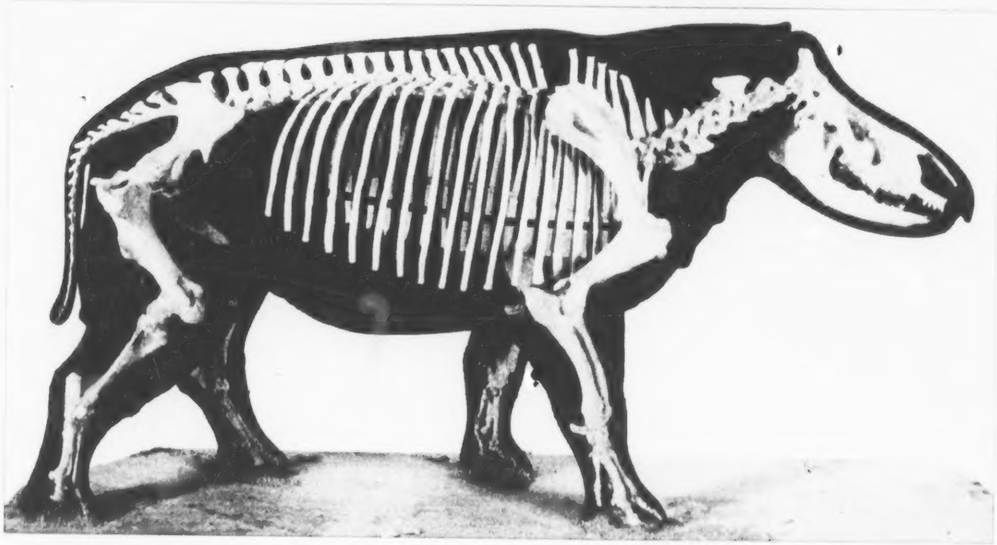
P.



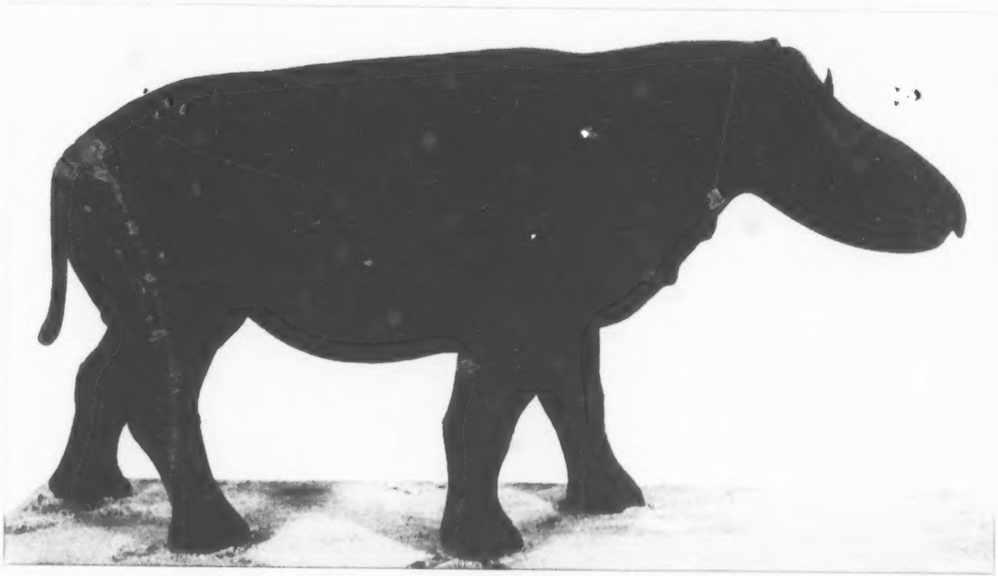
R.

TRIGONIAS

Don't show this page to students until Step 4 of METHODS.



Skeleton



Fleshed-out

As students in grades 5–8 extend their knowledge, what they know and are able to do includes:

- describing the importance of plant and animal adaptations, including local examples;
- creating and interpreting food chains and food webs;
- explaining the interaction and interdependence of nonliving and living components within ecosystems; and
- describing how an environment's ability to provide food, water, space, and essential nutrients determines carrying capacity.

As students in grades 9–12 extend their knowledge, what they know and are able to do includes:

- using and producing a variety of classification systems for organisms;
- predicting and describing the interactions of populations and ecosystems;
- explaining how adaptations of an organism determine its niche in the environment;
- explaining how changes in an ecosystem can affect biodiversity and how biodiversity contributes to an ecosystem's stability; and
- analyzing the dynamic equilibrium of ecosystems, including interactions among living and nonliving components.

3.4 Students know and understand how organisms change over time in terms of evolution and genetics.

In grades K–4, what students know and are able to do includes:

- identifying characteristics that are common to all individuals of a species;
- identifying characteristics of plants and animals that allow them to live in specific environments; and
- describing examples of extinct organisms based on fossil evidence.

As students in grades 5–8 extend their knowledge, what they know and are able to do includes:

- describing the role of chromosomes and genes in heredity; and
- describing evidence that reveals changes in groups of organisms over geologic time.

As students in grades 9–12 extend their knowledge, what they know and are able to do includes:

- giving examples to show how some traits can be inherited while others are due to the interaction of genes and the environment;
- describing how DNA serves as the vehicle for genetic continuity and the source of genetic diversity upon which natural selection can act;
- describing how mutation, natural selection, and reproductive isolation can lead to new species and explain the planet's biodiversity; and
- explaining why variation within a population improves the chances that the species will survive under new environmental conditions.

Standard 4: Students know and understand the processes and interactions of Earth's systems and the structure and dynamics of Earth and other objects in space.

4.1 Students know and understand the composition of Earth, its history, and the natural processes that shape it.

In grades K–4, what students know and are able to do includes:

- recognizing that fossils are evidence of past life.

As students in grades 5–8 extend their knowledge, what they know and are able to do includes:

- explaining how fossils are formed and used as evidence to indicate that life has changed through time.

As students in grades 9–12 extend their knowledge, what they know and are able to do includes:

- using evidence to investigate how Earth has changed or remained constant over short and long periods of time; and
- evaluating the feasibility of predicting and controlling natural events.

Standard 5: Students know and understand interrelationships among science, technology, and human activity and how they can affect the world.

In grades K–4, what students know and are able to do includes:

- recognizing the diversity of resources provided by the Earth and Sun; and
- identifying careers that use science and technology.

As students in grades 5–8 extend their knowledge, what they know and are able to do includes:

- describing advantages and disadvantages that might accompany the introduction of a new technology; and
- describing how people use science and technology in their professions.

As students in grades 9–12 extend their knowledge, what they know and are able to do includes:

- demonstrating the interrelationships between science and technology; and
- explaining the use of technology in an occupation.

BEST COPY AVAILABLE

Standard 6: Students understand that science is a particular way of knowing and understand common connections among scientific disciplines.

In grades K–4, what students know and are able to do includes:

- comparing knowledge gained from direct experience to knowledge gained indirectly;
- identifying observable patterns and changes in their lives and predicting future events based on those patterns; and
- comparing a model with what it represents.

As students in grades 5–8 extend their knowledge, what they know and are able to do includes:

- giving examples of how scientific knowledge changes as new knowledge is acquired and previous ideas are modified;
- identifying, comparing, and predicting variables and conditions related to change; and
- identifying and illustrating natural cycles within systems.

As students in grades 9–12 extend their knowledge, what they know and are able to do includes:

- explaining that the scientific way of knowing uses a critique and consensus process;
- using graphs, equations, or other models to analyze systems involving change and constancy;
- identifying and predicting cause-effect relationships within a system; and
- refining a hypothesis based on an accumulation of data over time.

READING, MATH, AND GEOGRAPHY

READING AND WRITING

Standard 1: Students write and speak for a variety of purposes and for diverse audiences.

Standard 2: Students read and understand a variety of materials.

Standard 3: Students apply higher-level thinking skills to their reading, writing, speaking, listening, and viewing.

Standard 5: Students read to locate, select, and make use of relevant information from a variety of media, reference, and technological sources.

MATH

Standard 1: Students develop number sense and use numbers and number relationships in problem-solving situations and communicate the reasoning used in solving problems.

Standard 3: Students use data collection and analysis, statistics, and probability in problem-solving situations and communicate the reasoning and processes used in solving problems.

Standard 5: Students use a variety of tools and techniques to measure and apply results in problem-solving situations and communicate the reasoning and processes used in solving problems.

GEOGRAPHY

Standard 1: Students know how to use maps, globes, and other geographic tools to locate and derive information about peoples, places, and environments.

Standard 3: Students understand how natural processes shape Earth's surface patterns and systems.

Standard 6: Students apply knowledge of people, places, and environments to understand the past and present and to plan for the future.

BEST COPY AVAILABLE

ADDITIONAL PREHISTORIC LIFE ACTIVITIES

AGE OF THE TRILOBITES TRAVEL POSTER AND BROCHURE

Describe a vacation to the ancient seas, early forests, *Time of the Dinosaurs,* or age of the mammals.

WORLD MAP OF DISCOVERIES

Keep track on a world map of current discoveries of major fossil sites.

SEASHELLS PAST AND PRESENT

Gather a collection of seashells. Have students compare these to fossils of ancient sea creatures. Are any of them the same? Which ancient sea creatures are still living in the seas today?

POTATO FOOTPRINTS

Carve ancient beast footprints into potatoes.

- Use different colors of ink or paint to represent the different animals.
- Use for adding or subtracting pictures.
- Make the animal footprints out of construction paper and use it as a nonstandard unit of measurement.

CREATIVE WRITING

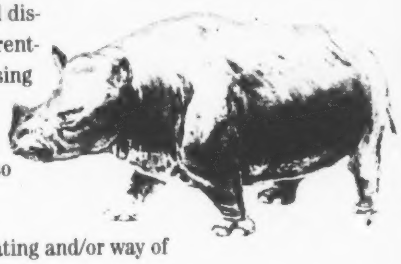
Use "What ifs" such as the following:

- What if you were shipwrecked and went back in time on an island of ancient creatures like the water-dwelling trilobites and eurypterids (sea scorpions), early amphibians, giant dragonflies, early horses, or woolly mammoths?
- What if you made the first early mammal discovery?
- What if the dinosaurs hadn't become extinct?
- What if you were accidentally locked in the *Prehistoric Journey* exhibit overnight?!
- What if you drank a potion that turned you into a *Dinohyus?*
- What if the dinosaurs reappeared today?
- What if you found a baby *Trigonias*?
- What if the dinosaurs had never existed—how would life be different today?

PREHISTORIC RHINO OR DINO RECORD BOOK

Research ancient rhinoceroses or dinosaurs at the library. Make a book with illustrations and facts that could include the following:

- Section listing smallest, fastest, shortest, or largest rhinos or dinos. Put in numerical order according to weights and sizes.
- List the advantages and disadvantages of the different-sized rhinos or dinos using defense, speed, eating habits, oldest, tallest, longest, heaviest, and so forth as categories.



- Classify according to eating and/or way of movement—walks or runs.
- Compare and contrast different types of teeth. What do they eat? How do they defend themselves? How do they care for their young?
- Study what time period they came from and whether changes in body structure through time were more advantageous to survival.
- Compare to modern rhinos or modern reptiles and birds.

CREATE A PREHISTORIC MUSEUM IN YOUR SCHOOL

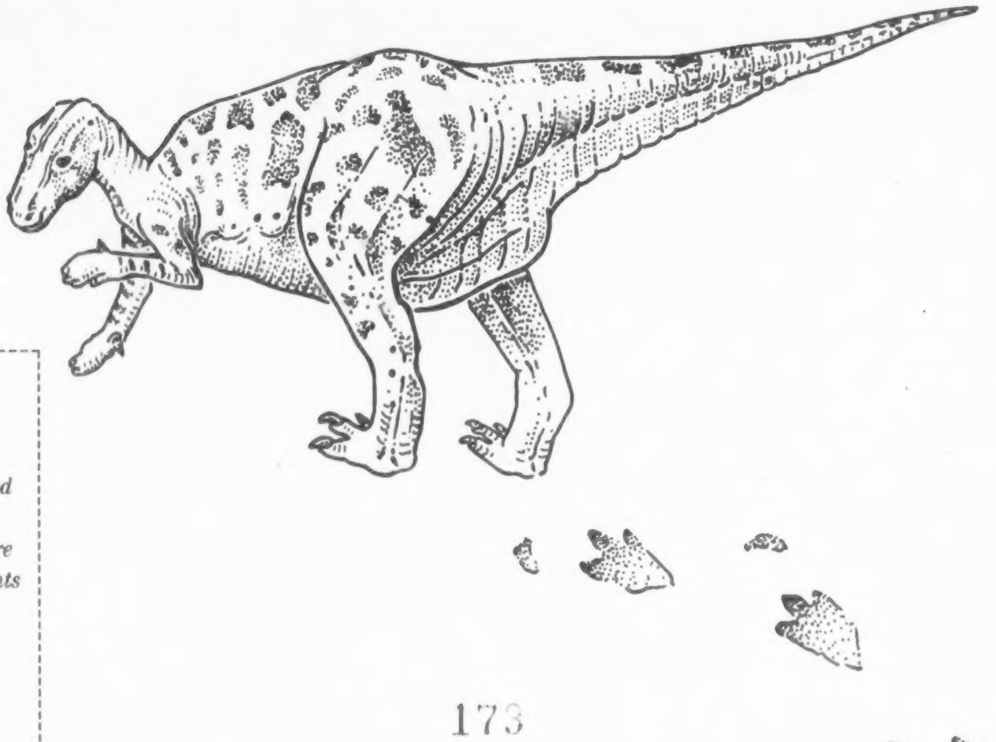
- Culminating activity after visiting *Prehistoric Journey*.

Appoint a child "museum guide" to guide visitors through a school museum set up in the cafeteria, gym, or throughout the hallways of the school with made-up artifacts and display halls and scenes drawn and made by children and their teachers. Have the tour end at prehistoric refreshments. Then have a performance with creature songs, poems, ancient story readings, dino dancing, and prehistoric puppets.

PREHISTORIC JOURNEY℠

INVOLVING PARENTS IN THE *PREHISTORIC JOURNEY* EXPERIENCE

We encourage you to photocopy the following two pages for the parents of your students either before or after your visit to *Prehistoric Journey*. Ask them to do several of the activities with their children—they should all have a lot of fun doing them.



TEACHER TIP

Opportunities for parents to participate, support, and extend their children's learning are essential. Here is a great chance for parents to take an active role and have fun too!

Margie Leitner
First Grade Teacher,
Lansing Elementary

PREHISTORIC JOURNEY℠

Denver Museum of Natural History
2001 Colorado Boulevard • Denver, Colorado 80205

FUN FOR PREHISTORIC PARENTS

The following creative ideas and activities will hopefully inspire you and your children to spend many fun-filled hours together either in conjunction with your visit to the Denver Museum of Natural History *or at home.*

Enjoy!

OLD MAIDOSAURUS

Using 3" x 5" index cards, paste pictures of dinosaurs on each one. Be sure to make two of each dino and one to be the Old Maidosaurus. To play, follow the rules of "Old Maid," choosing and trading cards to form pairs while trying to avoid getting stuck with Old Maidosaurus.

PLUCKY PALEONTOLOGY

- Piece together the skeleton of a chicken, explaining that paleontologists must piece together skeletons that are often incomplete—and don't forget that birds are the closest living relatives of dinosaurs!

SCRABBLESAUR, ANCIENT RIDDLES, AND OTHER GAMES

- Make words from prehistoric animal names and assign points to different letters similar to Scrabble.
- Make cards with dinosaur names on one set and translations on another. Use these cards to play Concentration and make a pair match.
- Scramble names of ancient creatures. Practice unscrambling them to figure out the name.

- Ancient Riddle Game—write riddles and share them. Example: My name means "other lizard"; I lived during the Jurassic Period; I was a meat-eater; I was about 35 feet long from my tail to my front jaw; I weighed 2 tons; my hind feet had three clawed toes; my jaws resembled crocodile teeth; Who Am I? (*Allosaurus*)

PREHISTORIC MASKS, PUPPETS, AND MOBILES

- Make prehistoric animal masks, puppets, or papier maché jewelry.
- Make an ancient animal or plant mobile that illustrates them and reinforces facts about each one.
- Put on a show and use your creations to make a home video of *Prehistoric Journey* Days.

INTERVIEW FRIENDS AND FAMILY

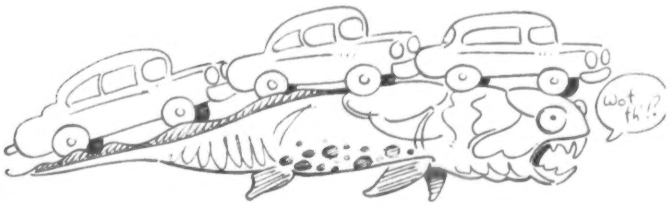
- Write, record, or video tape the answers of your family and friends to questions about prehistoric animals and dinosaurs (ask the following questions or make up your own):
- What would you do if you found a baby dinosaur in your backyard?
- Which dinosaur would you like to have for a pet? Why?
- What if dinosaurs lived today? What would they eat? How is our world different from theirs? (temperature, vegetation, and so forth)

©1995 Denver Museum of Natural History

SEALIFE LIMERICKS

- Write limericks that include facts on ancient beasts, for example:

There once was a fish—Dunkleosteus
Whose gigantic size seemed quite preposterous
He swam round with ease
Terrorizing the seas
All the other fish said please get Lost—eus!



DINO DANCING

- Move to music the way different dinosaurs might have moved, using pictures of dinosaurs, and relate their size and structure to how they moved. •Make up a dance about a dinosaur hatching from an egg. •Act out the cracking of the egg, the hatching, and the growth of the baby dinosaur. •For music, play your own (cymbals, wood blocks, other rhythm instruments). •"In The Mood" works well for the *"Brontosaurus"* Boogie.

WATCH THE FLINTSTONES OR OTHER "PREHISTORIC" SHOWS

Write a comparison of reality vs. fantasy of the prehistoric age.

DOT-TO-DOT MASTODONTS

- Make dot-to-dot numbered pictures of ancient and modern elephants.
- List all the words you can find in an ancient elephant name. For example: *Stegomastodon*: good, no, nod, man, done, and so forth. Other ancient elephants were the Woolly Mammoth and the Shovel-tusked Gomphothere.

FUN FAMILY FIELD TRIPS

Denver Museum of Natural History
Call (303) 322-7009 for reservations to *Prehistoric Journey*

Dinosaur Ridge
Dinosaur Ridge Visitor Center
Friends of Dinosaur Ridge
16831 W. Alameda Parkway
Morrison, CO 80465
(303) 697-3466

Florissant Fossil Beds National Monument
P.O. Box 185
Florissant, CO 80816
(719) 748-3253

CELEBRATION OF LEARNING

culminating activity after visiting *Prehistoric Journey*

- Appoint your child "museum guide" to guide you and other visitors through a homemade museum with made-up artifacts and display halls and scenes drawn and made by children. Have the tour end at prehistoric refreshments. Then have a performance with creature songs, primitive poems, ancient story readings, dino dancing, and prehistoric puppets.

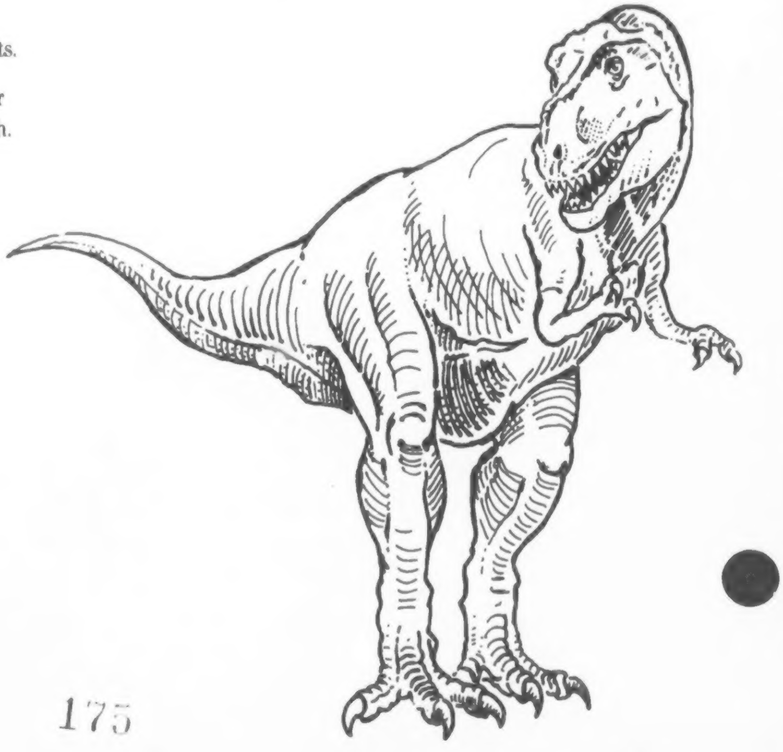
RESOURCES FOR PARENTS

Dixon, Douglas, Cox, Barry, Savage, R.J.G., Gardiner, Brian.
The Macmillan Illustrated Encyclopedia of Dinosaurs and Prehistoric Animals: A Visual Who's Who of Prehistoric Life.
New York: Macmillan Publishing Company with the American Museum of Natural History, 1988.

This is a fantastic source of pictures of prehistoric creatures. You could spend hours just looking through these pages at all the wonderful and bizarre animals that lived in the past, but you can also use these pictures as inspirations for your own pictures, dioramas, stories, songs, and poems about prehistory.

Fardon, John. Reader's Digest.
How the Earth Works—100 Ways Parents and Kids Can Share.
New York: The Reader's Digest Association, Inc., 1992.

If you have some extra time on the weekend to conduct educational, fun, and creative experiments and investigations with your children, this is an exciting resource.

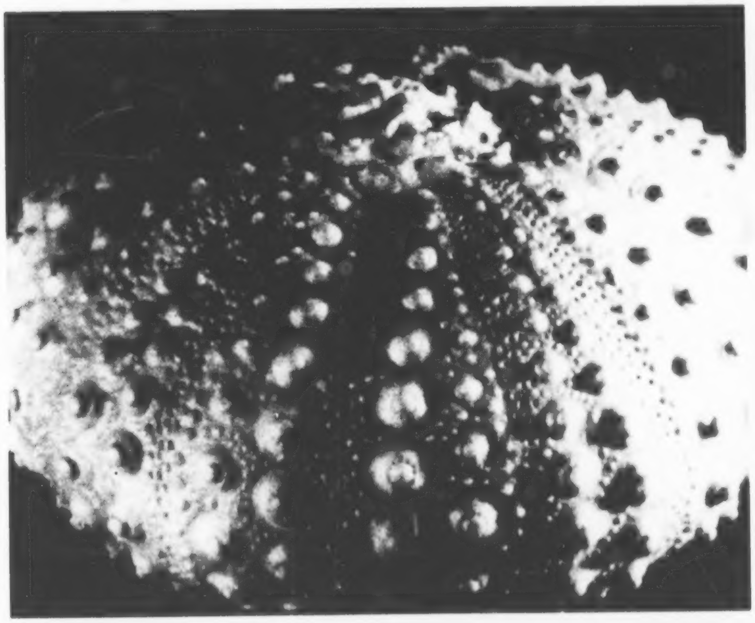


©1995 Denver Museum of Natural History

PREHISTORIC JOURNEY℠

ADDITIONAL TEACHER RESOURCES

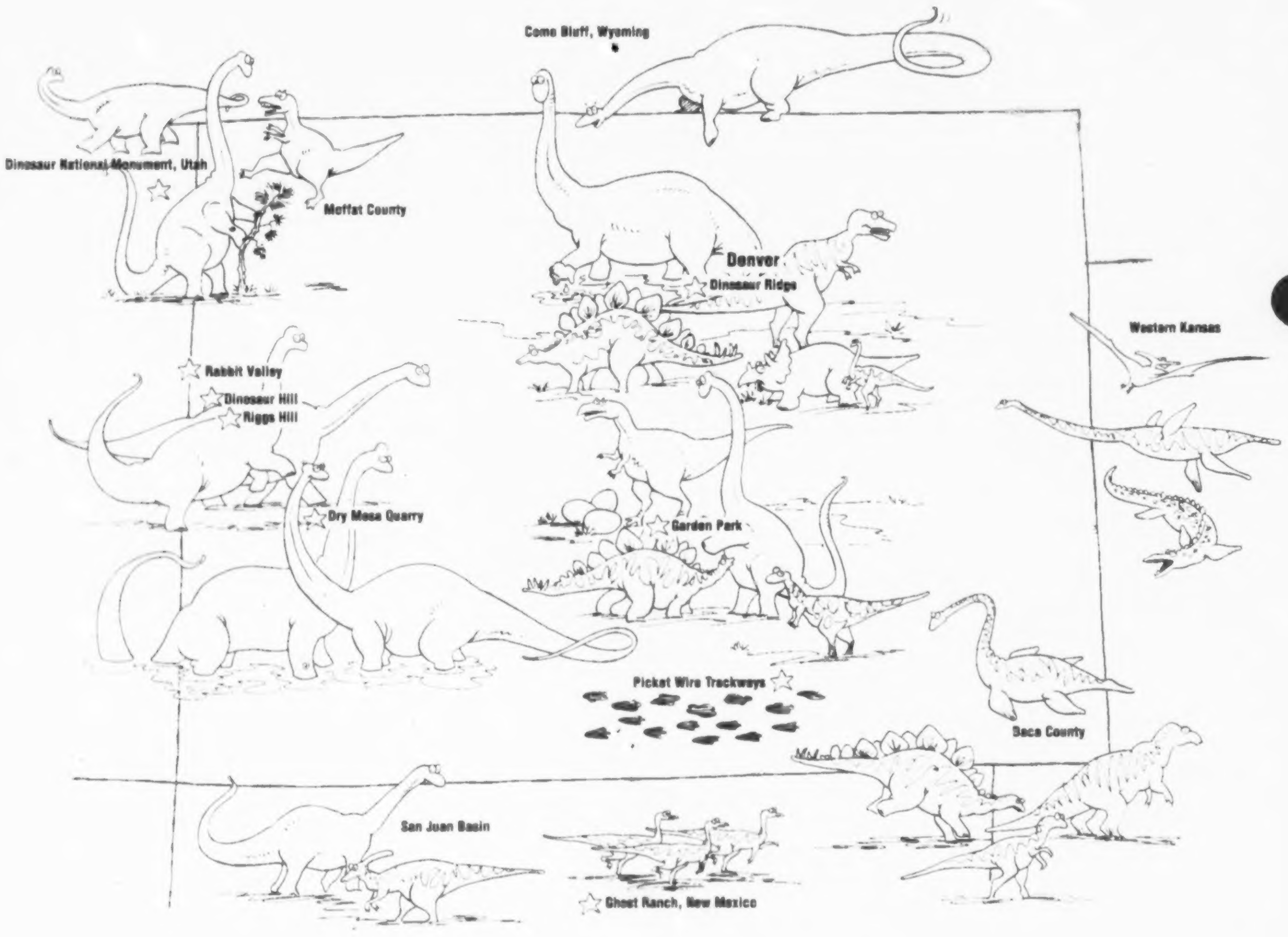
This section contains ideas for local field trips to fossil sites, important ethical and legal considerations when making fossil collections, a bibliography covering reference books as well as sources for more classroom activity ideas, and definitions of exhibit-related terminology with some pronunciations.



DINOSAURS IN DENVER?

Dinosaurs are closer than you think—many dinosaur fossils have been found in and around Denver. There are fossil sites as close as Littleton, Morrison, Cañon City, and downtown Denver. There are many more within a day's drive.

Sites marked with a ☆ are open to the public, so treat yourself to a fossil tour!


Como Bluff, Wyoming
Dinosaur National Monument, Utah
Moffat County
Denver
Dinosaur Ridge
Western Kansas
Rabbit Valley
Dinosaur Hill
Riggs Hill
Dry Mesa Quarry
Garden Park
Picket Wire Trackways
Baca County
San Juan Basin
Ghost Ranch, New Mexico

COLORADO CONNECTIONS: LOCAL FOSSIL FINDS AND FIELD TRIPS

The local fossil finds and field trips described here are within a reasonable driving range for Colorado residents. Some are located within the Denver metro area and are good field trip outings for you and your students. Many sites are wilderness and have trails with no water or facilities. Hiking boots and protective clothing are recommended, as are water bottles and hats. Please check with the individual contacts for up-to-date information.

DENVER METRO AREA

Dinosaur Ridge
Dinosaur Ridge Visitor Center
c/o Friends of Dinosaur Ridge, 16831 W. Alameda Parkway,
Morrison, Colorado 80465 (303) 697-3466

This area contains several track sites located on the eastern side of the Dakota Formation hogback found several miles north of Morrison, Colorado. During the Cretaceous Period, this area was on the western edge of an interior seaway. Some track sites have been fenced and marked with interpretive signs. The Friends of Dinosaur Ridge can be contacted for more information, literature, and field trips. Take C-470 to just north of Morrison. Continue north on Rooney Road several miles to the intersection with road 26. Continue west and the road climbs the east side of the hogback with the trackway.

I-70 Road Cut

Farther north from Dinosaur Ridge, I-70 cuts a swath directly through this north-south-running hogback. The exposure is 400 feet high and a half mile long. It exposes sediment from both the Jurassic and Cretaceous Periods, and exposes sandstones, mudstones, and shale deposited in a variety of ancient environments. An easy highway pullout, as well as a paved trail and interpretive signs, provide easy and safe access. Go west on I-70 from Denver, north at Morrison exit 259.

University of Colorado at Boulder—Henderson Museum
15th Street and Broadway, Boulder, Colorado (303) 492-6892

This research Museum has four halls open to the public, one of which has rotating exhibits. It is a great place to see local fossils, dinosaurs, and sea reptiles.

FLORISSANT

Florissant Fossil Beds National Monument
P.O. Box 185, Florissant, Colorado 80816 (719) 748-3253

During the Oligocene, a combination of volcanic ash and a large lake created conditions perfect for the preservation of fossils in the area of Florissant, Colorado. This area is a world-class locality for fossil insects and plants, and also has produced fossil fish, birds, and small mammals. The monument has a visitor's center that displays a beautiful collection of plant and insect fossils. Visitors may also walk a short trail to see sections of giant *Sequoia* preserved when volcanic mudflows encased their trunks. Located 45 miles west of Colorado Springs on Highway 24 to Florissant and 5 miles south of Teller County Route 1.

CAÑON CITY

Dinosaur Depot and Garden Park Fossil Area
330 Royal Gorge Blvd., Cañon City, Colorado (719) 269-7510

A rich area of dinosaur quarries has been excavated since 1870 where the first dinosaur bone in the western United States was found. The *Stegosaurus*, the *Othnielia*, and the fossil eggs on display in *Prehistoric Journey* were found here. The Dinosaur Depot is housed in a historic fire station and displays dinosaurs and fossils found in the area, particularly from the Garden Park fossil site. There are tours in the summer months and slide shows. It is located 8 miles north of Cañon City.

CLUBS AND ORGANIZATIONS:

Flatirons Mineral Club
P.O. Box 3331
Boulder, CO 80307

Western Interior Paleontological Society
P.O. Box 20011
Denver, CO 80220

Mile High Rock & Mineral Society
P.O. Box 81
Westminster, CO 80030

Friends of Dinosaur Ridge
Morrison Natural History Center
P.O. Box 564
Morrison, CO 80465

Garden Park Paleontology Society
P.O. Box 313
Cañon City, CO 81215-0313

BEST COPY AVAILABLE

GRAND JUNCTION, WESTERN SLOPE

Museum of Western Colorado (Dinosaur Valley)
362 Main, Grand Junction, Colorado (970) 241-9210

This museum has robotic dinosaurs, a bone preparation lab, and fossil displays. The museum also coordinates tours of three famous dinosaur sites in the area between Grand Junction and Fruita where more than 13 different kinds of dinosaurs have been found. There is a trail connecting these three sites.

Riggs Hill near Grand Junction—site of the world's first *Brachiosaurus* discovery.

Dinosaur Hill—1.5 miles south of Fruita on Highway 340—site of fossil *Apatosaurus* and *Diplodocus* discoveries.

Rabbit Valley: Trail Through Time is near Fruita, 25 miles west of Grand Junction on 1-70 at Exit 2. Historical quarry site where fossil *Camarasaurus*, *Apatosaurus*, and an *Iguanodon* have been found.

FRUITA

Devil's Canyon Science and Learning Center (Dinamation)
550 Crossroads Court, Fruita, Colorado (800) 344-3466

This center has a paleontology lab, simulated earthquake and volcanic displays, robotic dinosaurs, other prehistoric creatures, and research expeditions for visitors.

LA JUNTA

Picket Wire Canyon
Comanche National Grassland Office
1321 East Third Street, La Junta, Colorado (719) 384-2181

Look for the world's longest dinosaur trackway with over 1,300 dinosaur footprints found at the Purgatory River which reveal that apatosaurs and allosaurs once roamed along its banks. There is limited public access with no unauthorized motorized vehicles or camping allowed.

COLORADO/UTAH BORDER

Dinosaur National Monument
Dinosaur National Monument Headquarters and Visitor Center
Dinosaur, Colorado (970) 374-3000 or (801) 789-2115, Dinosaur National Monument quarry building & camping reservations line.

Dinosaur National Monument covers 328 square miles of land in northwestern Colorado and northeastern Utah. The Dinosaur Quarry contains an on-site dinosaur fossil bed located in Morrison sandstone. A permanent structure now houses the rock and its fossils. Other exhibits are found in the building, as well as a paleontology laboratory. The quarry has yielded tons of fossils, including a juvenile *Stegosaurus*, a juvenile *Camarasaurus*, and the *Diplodocus* on exhibit in *Prehistoric Journey*. The Dinosaur Quarry is found about 5 miles north of Jensen on Road 149.

UTAH

Utah Museum of Natural History
(801) 581-4303
University of Utah
Salt Lake City, UT 84112

Earth Science Museum
(801) 378-2232
Brigham Young University
1683 Campus Road
Provo, UT

Mill Canyon Dinosaur Trail
B.L.M. District Office
Moab, UT
On Highway 191 between Moab and Green River

College of Eastern Utah Prehistoric Museum
(801) 637-2788
Price City Hall
Castle County Travel Council
P.O. Box 1037
Price, UT 84501

Cleveland-Lloyd Dinosaur Quarry
(801) 637-4584
B.L.M., P.O. Drawer A.B.
Price, UT 84501
30 miles southeast of Price on dirt roads

Dinosaur Museum
of Natural History
Utah Field House
of Natural History
(801) 789-1352
Dinosaurland Travel
50 East Main
Vernal, UT 84078
20 miles west of Dinosaur National Monument on Highway 40

WYOMING

Como Bluff Dinosaur Graveyard and Museum
(800) 228-3547
Carbon County Visitors Council
Fifth and Walnut
Rawlins, WY 82301
7 miles east of Medicine Bow

Fossil Butte National Monument
P.O. Box 527
Kemmerer, WY 83101

WYOMING (continued)

Yellowstone National Park
P.O. Box 168
Yellowstone National Park, WY 82190

MONTANA

Museum of the Rockies
(406) 994-2251
Montana State University
South 7th and Kagy Boulevard
Bozeman, MT

NEBRASKA

Agate Fossil Beds National Monument
P.O. Box 427
Gerling, NE 69341

University of Nebraska State Museum
University of Nebraska
Merrill Hall
Lincoln, NE

KANSAS

Sternberg Museum
(913) 628-4286
Fort Hays State University
Fort Hays is located at I-70 and U.S. 183 in central Kansas.

NEW MEXICO

New Mexico Museum of Natural History
(505) 841-8837
1801 Mountain Road NW
Albuquerque, NM 87104

ARIZONA

Museum of Northern Arizona
P.O. Box 720
Flagstaff, AZ 86001

Grand Canyon National Park
P.O. Box 129
Grand Canyon, AZ 86023

Petrified Forest National Park
Petrified Forest National Park, AZ 86028

IF YOU ARE PLANNING TO COLLECT FOSSILS, KEEP THESE THINGS IN MIND.

Fossil collections can be extremely valuable resources in teaching about the history of life on Earth. However, there are many restrictions on acquiring fossil specimens, and there are important ethical considerations as well.

REGULATIONS

There are different regulations governing fossil collection on Bureau of Land Management, US Forest Service, National Park Service, state, and Indian lands. You must know these regulations before collecting fossils on these lands. In many cases, collecting is not allowed without a permit. It is illegal to collect any fossils on National Park Service lands. It is illegal to collect fossil vertebrates on any public lands without an appropriate permit. It is legal to collect for personal use, but not to dig or excavate, some invertebrate and plant fossils and petrified wood on Bureau of Land Management or US Forest Service lands, except in designated research areas. It is very important to check with the local Bureau of Land Management or US Forest Service office before picking up fossils on those lands. To collect on any state of Colorado lands, you must receive permission from the Colorado State Archaeologist's office (don't let this confuse you; most fossils are not *archaeological*—artifacts left behind by humans and also protected by strict regulations—they are *paleontological*—evidence of ancient life). It is illegal to sell fossils collected from public land—documentation must accompany fossil sales. To collect on private land you must ask permission from the landowner.

ETHICAL CONSIDERATIONS

Inappropriate collection of fossils can result in the destruction of important scientific information. Any potentially important fossil find should be left in the ground, exactly as it was found. You should then call appropriate scientific organizations that will ensure the fossils are collected in a way that will preserve their value to science. It is important to model good fossil-collecting behavior for students (see Investigation on pages 152–153 of this Sourcebook). When fossils are removed from their geological context without appropriate documentation, their relationships to time and other fossils are lost.

Sample Paleontological Locality Form

Permit #/Permittee: ______________________
Repository/Accn. # ______________________
Locality #: ______ ☐ Plant ☐ Vertebrate ☐ Invertebrate ☐ Other
Formation (and subdivision, if known): ______________________
Age: ____________ County: ______________________
BLM district: ________ Resource area: ______________________
Map name: ________ Map source: ______________________
Map scale: ________ Map edition: ______________________
Latitude (deg., min., sec., direction): ______________________
Longitude (deg., min., sec., direction): ______________________
or UTM Grid Zone: ______ ______mE ______mN
Survey (Sec., T & R): ______________________
Taxa collected/observed: ______________________
Collector: ______________________ Date: ____________
Remarks: ______________________

Taking the Museum's *Paleontology Certification Program* will give you all the information you need about collecting and preparing fossils *(for more information on this program, call 370-8287)*

Amateur paleontologists are those who are devoted to the science of paleontology but do not receive any monetary compensation. Every professional paleontologist begins as an amateur, and amateurs have contributed greatly throughout the history of paleontology. The original discoveries of dinosaurs at Morrison and Cañon City, Colorado, were made by two school teachers and amateur paleontologists, Arthur Lakes and O.W. Lucas.

In 1990, the Museum began the Certification Program in Paleontology for amateur paleontologists who want to learn more about paleontology and develop their skills in the collection and preservation of fossils. Students receive training in fossil preparation, field methods, geology, and the ancient history of life in the Rocky Mountain region. Both graduate and undergraduate credit is offered for some courses. Through cooperation with the Bureau of Land Management, the University of Colorado Museum, and the Office of the State Archaeologist in Colorado, graduates can receive sponsorship for their fieldwork and study on public lands. The program has become a model nationwide. Currently, other institutions in Texas, Arizona, Maryland, and California are initiating similar programs.

BEST COPY AVAILABLE

BIBLIOGRAPHY

Fossils and Earth's History

Colbert, Edwin H. ***The Great Dinosaur Hunters and Their Discoveries.*** New York: Dover, 1984.
This book is a history of worldwide paleontology.

Dixon, Dougal, and Raymond L. Bernor (eds.). ***The Practical Geologist***. New York: Simon and Schuster, Inc., by Quarto publishing, 1992.

Fenton, Carroll L., and Mildred A. Fenton. ***The Fossil Book***. New York: Doubleday, 1989.

Gould, Stephen J. ***The Book of Life: An Illustrated History of the Evolution of Life on Earth.*** New York: W.W. Norton & Co., 1993.
A well-illustrated summary of the history of life on Earth.

Howard, Robert W. ***The Dawnseekers***. New York: Harcourt Brace Jovanovich, 1975.
A rich history of paleontology in North America.

MacFall, Russell P., and Jay C. Wollin. ***Fossils for Amateurs: A Handbook for Collectors***. New York: Van Nostrand Reinhold, 1972.
One of the best books on collecting fossils for amateur.

Parker, Steve, and Raymond. L. Bernor (eds.). ***The Practical Paleontologist.*** New York: Simon and Schuster, Inc., by Quarto publishing, 1990.

Simpson, George G. ***Fossils and the History of Life***. New York: Scientific American Books, 1983.

Stanley, Steven M. ***Earth and Life Through Time.*** New York: W.H. Freeman and Company, 1989.
Stanley does an excellent job of elaborating on the geologic record, as well as the fossil record.

Walker, Cyril, and David Ward. ***Fossils***. Eyewitness Handbook. New York: Dorling Kindersley, Inc., 1992.

Evolution

Bishop, Beth A., and Charles W. Anderson. ***Student Conceptions of Natural Selection and Its Role in Evolution.*** Research Series No. 165, Michigan State University, East Lansing, February 1986.

Clough, Elizabeth E., and Colin Wood-Robinson. ***How secondary students interpret instances of biological adaptation***. *Journal of Biological Education*, Vol. 19, No. 2, 1985, pp. 125–130.

Ecker, Ronald L. ***Dictionary of Science and Creationism.*** Buffalo, New York: Prometheus Books, 1990.

Futuyma, Douglas J. ***Evolutionary Biology***. Sunderland, Massachusetts: Sinauer Associates, Inc., p. 565, 1979.
This is an in-depth text on evolutionary theory that could serve as a scientific resource for the details of evolutionary mechanisms.
Science on Trial: The Case for Evolution. New York: Pantheon Books, 1983, p. 251.

Gamlin, Linda. **Evolution**. New York: Eyewitness Science, Dorling Kindersley, 1993.
Richly illustrated, this book presents the evidence for evolution in an engaging fashion.

Milner, Richard. ***The Encyclopedia of Evolution: Humanity's Search for Its Origins.*** New York: Facts on File, Inc., 1990.

Mintzes, Joel J., and Mary Arnaudin. ***Children's Biology: A Review of Research on Conceptual Development in the Life Sciences***. North Carolina University, August 1984.

Nelkin, Dorothy. ***The Creation Controversy: Science or Scripture in the Schools***. W.W. Norton & Co., 1982.
This book recounts the history of the conflict between science and creationism.

Pankratius, William J. ***The constructivist transformation of a preservice science teacher's view on teaching creationism and evolution***. *Journal of Science Teacher Education*, Vol. 6, No. 1, 1995, p. 41–47.

Stansfield, William D. ***The Science of Evolution***. New York: Macmillan Publishing Co., 1977.

This book includes a good discussion of the nature of science and philosophy.

Ternes, Alan P., and Ellen Goldensohn, (eds.). ***Natural History.*** Vol. 103, No. 6, June. New York: American Museum of Natural History, 1994.

Whitfield, Philip. ***From So Simple a Beginning: The Book of Evolution***. New York: Macmillan Publishing Co., 1993.

PRECAMBRIAN / PALEOZOIC

Clarkson, E.N.K. ***Invertebrate Paleontology and Evolution.*** 3rd ed. London: Chapman and Hall, 1993.

Goldsmith, Donald, and Tobias Owen. ***The Search for Life in the Universe.*** Menlo Park, California: The Benjamin/Cummings Publishing Company, Inc., 1980.

This book discusses the origin of the universe, Earth, and life.

Gould, Steven J. ***Wonderful Life: The Burgess Shale and the Nature of History.*** New York: W.W. Norton & Co., 1989.

An entertaining look at the Burgess Shale, Ediacara, and other deposits that preserve early life. Easy to read and enlightening, but also controversial.

Margulis, Lynn, and Karlene V. Schwartz. ***Five Kingdoms: An Illustrated Guide to the Phyla of Life on Earth.*** New York: W.H. Freeman and Company, 1988.

Piel, Jonathan (eds.). ***Scientific American***. Vol. 253, No. 4. New York: Scientific American, Inc., October 1985.

Much of this magazine is devoted to the molecules of life.

MESOZOIC

Bakker, Robert T. ***The Dinosaur Heresies.*** New York: William Morrow and Co., 1986.

This is a very readable and entertaining account of the author's views on dinosaurs. It contains a fair bit of information about Western Interior dinosaurs and their alleged antics.

Barthel, K.W., N.H.M. Swinburne, and S. Conway Morris. ***Solnhofen.*** Cambridge: Cambridge University Press, 1990.

Benton, Michael J., Ph.D. ***The Reign of the Reptiles.*** New York: Crescent Books, 1990.

Dinosaur and Other Prehistoric Animal Fact Finder. New York: Kingfisher Books, Inc., 1992.

Colbert, E.H. ***Dinosaurs: An Illustrated History***. Maplewood, New Jersey: Hammond Publishing, 1983.

Corliss, Richard. ***Behind the magic of Jurassic Park.*** *Time Magazine*, Vol. 141, No. 17, April 26, 1993, pp. 49-50.

Czerkas, Sylvia J., and Everett C. Olson (eds.). ***Dinosaurs Past and Present.*** Vol. 1 & Vol 2. Natural History Museum of Los Angeles Seattle: University of Washington Press, 1986.

The wonderful thing about these two volumes is that they show the historical evolution of how paleontologists have perceived dinosaurs and how that perception has changed.

Dixon, Dougal, Barry Cox, R.J.G. Savage, and Brian Gardiner. ***The Macmillan Illustrated Encyclopedia of Dinosaurs and Prehistoric Animals.*** American Museum of Natural History. New York: Macmillan Publishing Co., 1988.

Good illustrations of a wide variety of fossil animals.

Folger, Tim. ***Dinosaurs 1992.*** *Discover,* Vol. 14, No. 1, January 1993, pp. 48–50.

Glut, Donald F. ***The New Dinosaur Dictionary.*** New Jersey: Citadel Press, 1982.

Goldensohn, Ellen, (eds.). ***Natural History Magazine.*** Vol. 104, No. 6. New York: American Museum of Natural History, June 1995.

This whole magazine is devoted to dinosaurs.

Gore, Rick. ***The March Toward Extinction.*** *National Geographic*, Vol. 175, No. 6, June 1989, pp. 662–699.

Dinosaurs. *National Geographic*, Vol. 183, No. 1, January 1993.

Horner, John R. ***Digging Dinosaurs***. New York: Workman Press, 1988.
Gives a good feel of fieldwork.
Lemonick, Michael D. ***Rewriting the Book on Dinosaurs.*** *Time Magazine*, Vol. 141, No. 17, April 26, 1993, pp. 42–47.
Lockley, Martin. ***Tracking Dinosaurs***. Cambridge, New York: Cambridge University Press, 1991.
Popular account of figuring out dinosaur tracks.
McGowan, Christopher. ***Dinosaurs, Spitfires & Sea Dragons***. Cambridge, Massachusetts: Harvard University Press, 1992.
Norman, Dr. David. ***The Illustrated Encyclopedia of Dinosaurs.*** New York: Crescent Books, 1985.
One of the best general dinosaur books with amazing reconstructions of the giant creatures.
The Poster Book of Dinosaurs. New York: Crescent Books, 1987.
Great for classroom posters!
Weishampel, David B., Peter Dodson, and Halszka Osmolska (eds.). ***The Dinosauria***. Berkeley: University of California Press, 1990.
Wellnhofer, Peter. ***Illustrated Encyclopedia of Pterosaurs***. London: Salamander Books, 1991.
Excellent reconstructions of the flying reptiles.

CENOZOIC

Guthrie, R. Dale. ***Frozen Fauna of the Mammoth Steppe: The Story of Blue Babe***. Chicago: University of Chicago Press, 1990.
A great overview of the fauna of the Pleistocene in North America. Mostly about "Blue Babe," which is a frozen fossil bison.
Harris, Marvin. ***Our Kind***. New York: Harper & Row Publishers, Inc., 1989.
Johanson, Donald, and Eddy Maitland. ***Lucy: The Beginnings of Mankind.*** New York: Warner Books, Inc., 1981.
Johanson, Donald, Lenora Johanson, and Blake Edgar. ***Ancestors: In Search of Human Origins***. New York: Villard Books, 1994.
Kürten, Bjorn ***The Age of Mammals***. New York: Columbia Press, 1971.
Good introduction to mammal evolution in the Cenozoic.
Leakey, Richard E. and Roger Lewin. ***Origins Reconsidered***. New York: Bantam Doubleday Dell Publishing Group, Inc., 1992.
Leakey, Richard E., and Alan Walker. ***Homo erectus unearthed***. *National Geographic*, Vol. 168, No. 5, November 1985, pp. 624–629.
Lewin, Roger. ***Human Evolution: An Illustrated Introduction.*** 3rd ed. Cambridge, Maine: Blackwell Science Publications, Inc., 1995.
Savage, R.J.G., and M.R. Long. ***Mammal Evolution: An Illustrated Guide***. New York: Facts on File Publications, 1986.
Stringer, Christopher, and Clive Gamble. ***In Search of Neanderthals***. New York: Thames and Hudson, Inc., 1993.
Trinkaus, Erik, and Pat Shipman. ***The Neanderthals.*** New York: Vintage Books, 1994.
Weaver, Kenneth F. ***The search for our ancestors***. *National Geographic*, Vol. 168, No. 5, November 1985, pp. 561–623.
Zihlman, Adrienne L. ***The Human Evolution Coloring Book.*** New York: Barnes and Noble Books, 1982.

Extinction

Stanley, Steven M. ***Extinction***. New York: Scientific American Books, 1987.

Ward, P.D. ***On Methuselah's Trail: Living Fossils and the Great Extinctions***. New York: W.H. Freeman and Company, 1992. *An easy read about evolution and extinction.*

The End of Evolution. New York: Bantam Books, 1994.
A well-written account of the three big extinctions in Earth's history.

Plants and Paleobotany

Dorros, A. ***Rain Forest Secrets***. New York: Scholastic Inc., 1980.

Eyewitness Visual Dictionary of Plants. New York: Dorling Kindersley, Inc., 1992.

Kirkpatrick, R. ***Leaves***. Raintree, Steck Vaughn, 1991.

Fultz, Sara A., Peter M. Ray, and Taylor A. Steeves. ***Botany***. Philadelphia: Saunders College Publishing, 1982.

Ortleb, E. ***Studying Plants***. St. Louis: Milliken Publishing Co., 1986.

Stewart, Wilson N., and Gar W. Rothwell. ***Paleobotany and the Evolution of Plants***. 2nd ed. Cambridge: Cambridge University Press, 1993.
Recommended by our paleobotanist as an excellent textbook on paleobotany.

Tidwell, William D. ***Common Fossil Plants of Western North America***. Provo: Brigham Young University Press, 1975.
One of the best in the West for descriptions of fossil plants.

White, Mary E. ***Flowering of Gondwana***. Princeton: Princeton University Press, 1990.

Natural History of Colorado

Chronic, Halka. ***Roadside Geology of Colorado***. Missoula, Montana: Mountain Press Publishing Co., 1980.
Take a road trip through time!

Geologic Atlas of the Rocky Mountain Region. Denver: Rocky Mountain Association of Geologists, 1972.
The "Big Book" on the stratigraphy of the Western Interior of North America, still available through the Tattered Cover at a reasonable price.

Jenkins, John T., Jr., and Janice L. Jenkins. ***Colorado's Dinosaurs***. Denver: Colorado Geological Survey Publications, 1993.

Kent, H.C., and K.W. Porter (eds.). ***Colorado Geology***. Denver: Rocky Mountain Association of Geologists, 1980.
Good general overview of the geology of Colorado.

Mutel, Cornelia F., and John C. Emerick. ***From Grassland to Glacier: The Natural History of Colorado***. Boulder: Johnson Books, 1984.

Sources for Activities

Bartos, Diana Scheidle, Mack Fair, Stephen L. Gigliotti, and Rita Perron. ***Paleontology and Dinosaurs: Earth Science Module for Grades 7–9***. Denver Earth Sciences Project (DESP), Office of Special Programs and Continuing Education, Colorado School of Mines.
This course curriculum, developed in partnership with the Denver Museum of Natural History, consists of a comprehensive student curriculum to learn basic paleontological concepts such as the formation of fossils, relative and radiometric dating of rocks, and geologic time. The high-interest module integrates geography and mathematics with traditional geological concepts to give students a look at real-life paleontology. Students will collect data and make some interpretations about dinosaurs by using maps, fossil bones, and teeth. For more information on the Denver Earth Sciences Project call Marsha Barber at (303) 273-3494.

Burne, David. ***How Nature Works: 100 Ways Parents and Kids Can Share the Secrets of Nature***. Pleasantville, New York: The Reader's Digest Association, Inc., 1991.

Change over Time. New York: Scholastic Inc., 1995.

The Scholastic Science Place's ***Change over Time*** *teacher kit was developed in cooperation with the Denver Museum of Natural History. It contains a complete teaching unit on evolution targeted at the 5th grade level. The unit bag contains everything you need to teach the unit, including:*

- *Student guides and worksheets*
- *Teacher's map to exploration*
- *A video and children's books on evolution*
- *All the materials you need for your class to do the hands-on activities*

For more information, call (800) 325-6149.

Farndon, John. ***How the Earth Works: 100 Ways Parents and Kids Can Share the Secrets of the Earth***. Pleasantville, New York: The Reader's Digest Association, Inc., 1991.

Hann, Judith. ***How Science Works: 100 Ways Parents and Kids Can Share the Secrets of Science***. Pleasantville, New York: The Reader's Digest Association, Inc., 1991.

Munsart, Craig A. ***Investigating Science with Dinosaurs***. Englewood, Colorado: Libraries Unlimited, Inc., 1993.

Excellent resource.

Simmons, Roberta, Nancy Thomas, and Carol Beckman. ***DinoSauring: A "Channels to Children" Activity Guide***. Colorado Springs: Channels to Children, Inc., 1989.

VanCleave, Janice. ***Earth Science for Every Kid: 101 Experiments That Really Work***. New York: John Wiley & Sons, Inc., 1991.

REFERENCES FOR STUDENTS

Brandenburg, Aliki. ***Digging up Dinosaurs***. New York: Harper & Row Publishers, 1988.

Fossils Tell of Long Ago. New York: Harper Collins Publishers, 1990.

Courtenay-Thompson, Fiona, and Mary Lindsay (eds.). ***The Visual Dictionary of Dinosaurs***. Eye Witness Visual Dictionaries. New York: Dorling Kindersley, Inc., 1993.

Emberley, Michael. ***Dinosaurs!*** Boston: Little, Brown and Co., 1980.

Katz, A. ***Naturewatch: Exploring Nature with Your Children***. Reading, Maine: Addison-Wesley, 1992.

Lauber, Patricia. ***Dinosaurs Walked Here and Other Stories Fossils Tell***. New York: Macmillan Publishing Co., First Aladdin Books, 1992.

Milburn, Charles. ***Let's Look at Dinosaurs***. Bookwright Press, 1987.

Parker, Steve. ***Science Discoveries: Charles Darwin and Evolution***. New York: Scholastic Inc., 1992.

Peterson, Roger T., John Kricher and Gordon Morrison. (eds.). ***A Field Guide to Dinosaurs Coloring Book***. Boston: Houghton Mifflin Co., 1989.

VanCleave, Janice. ***Dinosaurs for Every Kid***. New York: John Wiley & Sons, Inc., 1994.

West, Linda. ***Dinosaurs and Dinosaur National Monument: A Resource Packet for Students and Teachers***. Dinosaur Nature Association, 1985.

Whitfield, Philip. ***Macmillan Children's Guide to Dinosaurs and Other Prehistoric Animals***. New York: Macmillan Publishing Co., 1992.

SCIENCE TEACHING

Benchmarks for Science Literacy. Project 2061. American Association for the Advancement of Science. New York: Oxford University Press, 1993.

DeBruin, J. ***School Yard–Backyard Cycles of Science***. Carthage, Illinois: Good Apple, 1989.

Rutherford, F. James and Andrew Ahlgren. ***Science for All Americans***. New York: Oxford University Press, 1990.

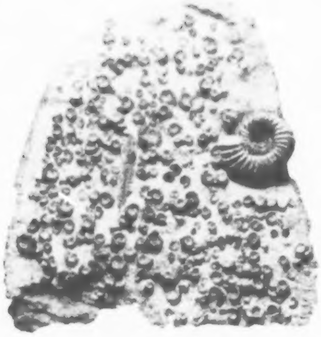
GLOSSARY

A

adaptation
A characteristic of an organism that makes it better able to survive and reproduce in its environment. (Also the process through which this occurs.)

Allosaurus fragilis—al-o-SORE-us fra-JILL-us
Allosaurus was a large carnivorous dinosaur from the Late Jurassic Period in the western United States, originally found in Garden Park in Colorado. Equipped with razor-sharp teeth and sharp claws, it was a potent threat to plant-eaters such as *Diplodocus* and *Stegosaurus. Allosaurus* can be distinguished from *Tyrannosaurus rex* by the number of claws on its "hands": It has three, as opposed to two for *Tyrannosaurus rex*.

amber
Hardened tree sap that sometimes preserves original organic material from the past—prehistoric insects and plants have been found preserved in fossil amber.



ammonites

ammonites—AM-uh-nites
Extinct, chambered, shelled cephalopods (relatives of modern squid, octopus, and nautilus) that were abundant in Mesozoic seas. Many had coiled shells.

amphibians
Animals, like modern frogs and salamanders, that are able to live both on land and in water. Their skin dries out when away from water. Ancient amphibians were the first vertebrates to live on land.

angiosperms
Flowering plants. They protect their unfertilized seeds inside flowers and can reproduce faster than any other seed plants. They first appeared about 120 million years ago. Most of the plants in today's world are flowering plants.

Archaeopteryx—are-key-OP-ter-icks
The earliest known indisputable bird fossil. The 150-million-year-old transitional form had birdlike feathers and a long, bony dinosaur tail. Its name means "early wing."

arthropods—ARE-throw-pods
Animals with jointed legs and exoskeletons like insects, spiders, crabs, and shrimp.

Australopithecus afarensis—awe-strall-o-PITH-ih-cuss aff-are-EN-sis
The earliest known hominid—small, upright-walking, and ape-like—dating to nearly 4 million years ago. The name means "southern ape from Afar" because the fossil skeletons of this hominid were found in the Afar region of northern Ethiopia.

B

bacteria
Primitive, microscopic, single-celled organisms without a nucleus.

baculites—BACK-you-lites
Uncoiled (straight-shelled) relatives of ammonites.

birds
Feathered vertebrates that evolved from small, bipedal, carnivorous dinosaurs. Almost all Mesozoic birds had teeth.

bison
A large, herding mammal commonly known as the American "buffalo." Early bison were large, standing nearly as tall as elephants with horns sometimes 6 feet across.

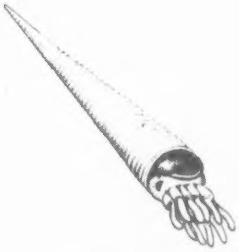
brachiopods—BRACK-ee-o-pods
Shelled sea creatures that look a little like clams and oysters but are not closely related to them. Their shells, feeding, and breathing structures are different from those of clams, and their shells stay closed with little effort.

Brachiosaurus—brack-ee-o-SORE-us
One of the largest, tallest dinosaurs, which stood as tall as a four-story building, and weighed an incredible 89 tons. This giant fed on plants with pointed peglike teeth and has been found in Garden Park, Colorado, and near Grand Junction, Colorado.

C

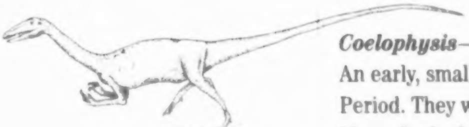
carnivore
Meat-eater, characterized by sharp teeth for cutting flesh.

cephalopod—SEF-uh-low-pod
The group of organisms including the modern squid, nautilus, and octopus, and extinct ammonites and baculites. They propel themselves by sucking in water and ejecting it—like a jet engine—with tentacles trailing behind. Ancient cephalopods were fast swimmers and active predators. Some grew to be as long as a station wagon!


cephalopod

chalicothere—call-EEK-o-theer
Early Miocene animal with long front legs, clawed feet like a sloth, the body of a rhino, and a face like a horse! They lived as recently as 10,000 years ago, but have no living relatives.

climate
The long-term results of daily weather patterns, including the average temperature, average precipitation, and seasonal variation.


Coelophysis

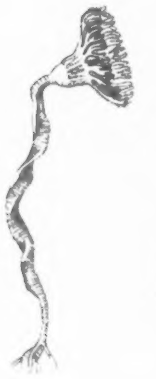
Coelophysis—see-low-FY-sis
An early, small, predatory dinosaur that grew up to 10 feet in length and lived in the Late Triassic Period. They were meat-eating hunters with many small, sharp teeth and claws that could grasp prey. Many *Coelophysis* skeletons have been discovered in a quarry at Ghost Ranch in New Mexico.

cold-blooded (ectotherm)
Animal whose temperature depends completely on its surroundings and that tends to be less active than warm-blooded animals.

convergent evolution
Occurs when unrelated groups of animals become independently adapted to the same environment; for example reptiles, mammals, and birds have all evolved flight and swimming.

coprolite
Fossilized dung or excrement. Some coprolites can be studied to determine what animals were eating—for example, some contain fish scales.

Cretaceous seaway
A sea that covered an area stretching from Utah to Minnesota and from the Arctic to the Gulf of Mexico between 95 million and 68 million years ago.



crinoid

crinoid—CRY-noid
Though crinoids are known as sea lilies, they are animals, not plants. They are related to starfish and sand dollars, and use their feather-like arms to filter tiny microorganisms from seawater.

cycads
Short, stubby plants with frond-like leaves and seed-bearing cones. They look like palms, but are related to pines, and are tropical to subtropical.

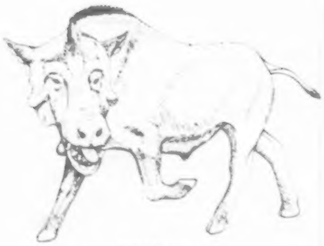
D

Desmatosuchus—dez-MAT-o-sook-us
A plant-eating, thecodont reptile from the Triassic Period.

Diatryma—dye-uh-TRY-muh
A giant, flightless predatory bird from the Early Eocene Epoch, with an enormous head and beak, a thick neck, small wings, and stout legs. It stood up to 7 feet tall and weighed as much as 300 pounds.

Dimetrodon—dye-MET-row-don
This predator from the Early Permian Period was equipped with massive canines, well-developed shearing teeth, and skull structures that identify it as protomammal. Its finbacked sail may have functioned like a solar heater.

Dinohippus—dine-o-HIP-us
Ancient horses living in North America 8 million years ago; the genus included both three-toed and one-toed species. These grazers gave rise to the genus *Equus*, or modern horses.



Dinohyus

Dinohyus—dye-no-HIGH-us
A giant pig-like predator (an entelodont) that lived 20 million years ago in the Early Miocene Epoch. Skeletons of this relative of modern camels, pigs, and hippopotamuses have been found in the Agate Springs fossil area in northwestern Nebraska.

dinosaur
A specialized group of reptiles that lived on land from 215 million to 66 million years ago during the Mesozoic Era. The first dinosaurs were small, though many later grew to be huge. Dinosaurs had upright posture, specialized ankle bones, were active, and may have been warm-blooded. The closest living relatives to dinosaurs are birds.

Diplodocus longus—dip-LAUD-uh-cuss LONG-us
A huge, herbivorous dinosaur, characterized by a long neck and tail, that is found in the Morrison Formation of Utah, Colorado, and Wyoming. It lived between 156 million and 150 million years ago. The skeleton on exhibit is from Dinosaur National Monument in eastern Utah. The first *Diplodocus* was found in Colorado.

DNA

DNA (deoxyribonucleic acid)
The molecule that allows living things to reproduce. It acts like a blueprint or a computer program, directing the assembly of amino acids into protein molecules that control the growth and development of the organism.

Dunkleosteus—DUNK-lee-OST-ee-us
A huge, armored Devonian Period fish that ate primitive sharks. Its head was covered with bony plates. It had a huge mouth and very strong jaws, but no teeth. The sharp edges of its jaws served perfectly well to slice up prey. It could reach lengths of 11 feet or more.

18

E

ecosystem
A recognizable grouping of plants, animals, and environmental conditions, and the interactions among them.

Edmontosaurus—ed-mon-toe-SORE-us
A duckbilled dinosaur, characterized by its rather flattened, crestless head, that lived between 70 million and 66 million years ago. It had over 1,800 teeth. The skeleton on exhibit was collected in Montana.

Equus
The first horses in this genus lived about 3 million years ago. They looked like modern horses, with a single toe—or hoof—and the teeth and jaw of a grazer. Some species migrated to Asia, Africa, and Europe at a time when North America and Asia were still connected by a land bridge. Modern horses and zebras are members of the genus *Equus*.

Eryops—EAR-ee-ops
A large, carnivorous amphibian from the Early Permian Period that was active and spent most of its time on land.

eurypterids—you-RIP-ter-ids
These "sea scorpions" swam in the Paleozoic seas and had large claws for seizing prey. Modern scorpions, horseshoe crabs, and spiders are relatives of the extinct eurypterids.

eurypterid fossil slab

evolution
Change in the characteristics of a population of organisms over a series of generations—change through time.

extinction
Death of all members of a species.

F

fossil
Evidence of ancient life—any remains, traces, or imprints of an organism that have been preserved from some past geologic time.

fossil record
The history of life on Earth as revealed by fossil remains.

fossilization
A geological process in which the remains of past organisms are preserved, replaced, or impregnated by minerals.

G

gastrolith
Stones swallowed by an animal, like modern crocodiles and birds, to aid in digestion of plant material. These smooth "stomach stones" have been found in association with some plant-eating dinosaur skeletons.

gene
The fundamental unit of heredity, composed of DNA.

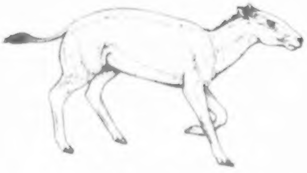
Gomphotherium—GOM-foe-THEER-ee-um
An ancient elephant from the Late Miocene Epoch, about 7 million years ago. This shovel-tusker—so called because of flattened tusks and elongated lower jaws—was a vegetarian, like other elephants.

H

hadrosaurs
Duckbilled dinosaurs, some of which had fantastic display structures in the shape of crests on their heads, and skin frills running from the neck to the end of the tail. They were probably social animals that lived and traveled in groups. They laid their eggs in nests and some took care of their babies after they were born.

herbivore
An animal that eats plants.

hominids
Hominids—the human family—evolved more than 4 million years ago. All walked upright on two legs.



Hyracotherium

Hyracotherium—high-rack-oath-EAR-ee-um
Small, browsing animals with four toes on their front feet and three toes on their rear feet that lived almost 57 million years ago. They were among the first horses in North America, and were formerly referred to by the name *Eohippus*, or the dawn horse.

I

ichthyosaurs—ICK-thee-o-sores
Ichthyosaurs were swimming reptiles that lived from the Early Triassic Period through the Early Cretaceous Period. They resembled dolphins in their proportions, though some grew to be much larger (up to 50 feet). The specimen on display is a *Stenopterygius* from Germany.

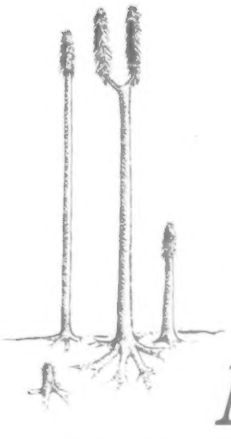
index fossil
A fossil that indicates a specific time period.

invertebrates
Animals without backbones.

K

K-T Boundary
Refers to the layer where the last rocks from the Cretaceous Period meet the first rocks from the next period, called the Tertiary Period. The K-T boundary rock layer contains iridium, a metal that is rare on Earth, but common in asteroids. It was the first clue that an asteroid impact could have caused the death of the dinosaurs. "K" is a geologist's abbreviation for the Cretaceous Period, and "T" is for the Tertiary Period.

K-T Extinction
Refers to the extinction, around 65 million years ago, when the dinosaurs and many other Cretaceous Period plants and animals died out.



lycopod trees

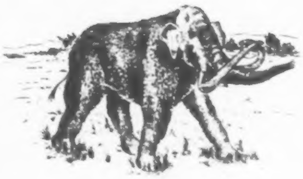
L

lycopod—LIKE-o-pod
Huge-scale trees that grew in an unusual way, with the entire top growing slowly upward and then branching out at the top before it stopped growing completely. Its spores were carried off by the wind to start new trees. Shortly after, the grown tree died.

M

Maiasaura—my-o-SORE-uh
Maiasaura, "the good mother lizard," was a close relative of *Edmontosaurus*. Discoveries of eggs, nests, and babies have given insight into dinosaur egg-laying, nesting, and child-rearing behavior.

mammals
Fur-bearing, warm-blooded animals that nurse their young. Mammals evolved during the Early Triassic Period. Early fossil mammals are distinguished from reptiles (and the common ancestors of reptiles and mammals) by their specialized jaw joint and other skull features. While a reptile's jaw is composed of four bones, a mammal's jaw is composed of one bone. The other bones of the reptile jaw have evolved into the bones of the mammal inner ear. All three major modern groups of mammals—monotremes, marsupials, and placentals—had appeared by the end of the Cretaceous Period.



mammoth

mammoth
Extinct relatives of elephants that grazed on Late Cenozoic grasses and low shrubs. They had huge teeth with flat, grate-like chewing surfaces.

mastodon
Extinct relatives of elephants that foraged in Late Cenozoic forests with teeth covered with large, round, crushing cusps.

mosasaurs—MOZE-uh-sores
Seagoing, carnivorous lizards of the Late Cretaceous Period. They were swift marine predators, similar to killer whales and dolphins. The specimen on display (*Platecarpus*) was found in Kansas in 1937. It is 18 feet 9 inches long and lived approximately 84 million years ago.

mutation
Random errors in the transfer of genetic information that introduce brand-new characteristics.

N

natural selection
Natural selection, the major mechanism of evolution, is the differential survival and reproduction of genotypes.

Notharctus
An arboreal, Eocene Epoch, lemur-like primate that grew to the size of a large house cat. Fossils of *Notharctus* have been found in Wyoming.

O

oreodont—OR-ee-o-dont
A grazing and browsing animal from the Early Miocene Epoch, which looked like a cross between pigs and sheep. They are related to modern pigs and camels.

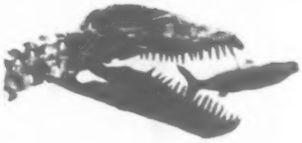
P

paleoecology
The science of the relationship between ancient organisms and their environment.

paleontology
The study of past life and fossils.

Pangaea
A supercontinent that existed during the Late Paleozoic Era.

phytosaur—FY-toe-sore
A giant, thecodont reptile (resembling a crocodile though not closely related) that lived during the Triassic Period.



plesiosaur

plesiosaur—PLEASE-ee-uh-sore
A marine reptile of the Mesozoic Era. The ones on display *(Thalassomedon*—95 million years ago) are casts of the original skeleton, which is in the scientific collections of the Denver Museum of Natural History and was found in Baca County, Colorado. The Museum's specimen is the type, or the very first one found and studied of this animal.

preparation
The removal, cleaning, and reconstruction of fossils by a preparator to allow their study by paleontologists, and possibly their exhibition in a museum.

primates
Tree-dwelling mammals with binocular vision, rotating shoulders, and specialized dentition that evolved 60 million years ago in Africa as forests expanded, and later migrated to Asia, Europe, and North and South America. Humans are primates.

pterosaurs

protomammal
Protomammals, synapsids and therapsids, originated during the Paleozoic Era. Mammals evolved from protomammals. Reptiles and mammals share a common ancestor.

pteridosperm—ter-ID-uh-sperm
An extinct seed fern that reproduced by seeds. Although they looked like ferns, they were not, because true ferns reproduce by spores.

pterosaurs—TAIR-o-sores
Flying reptiles of the Mesozoic Era whose fourth fingers were elongated to support their wings. There were hundreds of kinds of pterosaurs, in all shapes and sizes. The largest was as big as a twin-engine airplane, and the smallest, the size of a sparrow. They became extinct at the end of the Cretaceous Period.

R

radiation
Divergence of members of a lineage of organisms into different niches and new species.

reef
A wave-resistant structure dominated by a rigid framework of organisms. Many modern reefs are formed by coral, though other groups of organisms, like ancient clams and algae, formed reefs in the past.

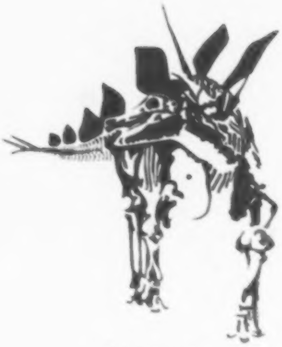
reptiles
A class of scaled, air-breathing vertebrates. Modern reptiles such as crocodiles, turtles, lizards, and snakes first appeared during the Mesozoic Era. Extinct reptiles include dinosaurs, plesiosaurs, pterosaurs, and ichthyosaurs.

S

sexual dimorphism
When males and females of the same species have different features, such as size, antlers, or coloration.

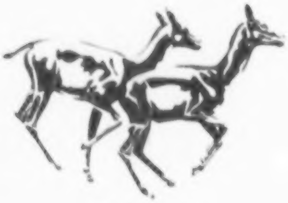
speciation
The origin of a new species from members of a preexisting species.

species
A group of individuals that share common characteristics and ancestry and can mate to produce fertile offspring (this is the definition of a biological species—defining a species in the fossil record obviously requires different criteria).



Stegosaurus

Stegosaurus stenops—steg-o-SORE-us STEN-ops
Stegosaurus, which means "lizard with a roof," was an herbivore from the Late Jurassic Period. It had large plates along its back and spikes on its tail. The plates on its back may have been used for protection, for keeping the animal's body temperature within a constant range, or as signaling devices. It lived between 156 million and 150 million years ago. *Stegosaurus* was chosen as the Colorado state fossil in 1982. There are important sites in Colorado, particularly the sites in Garden Park north of Cañon City, where Museum paleontologists recently discovered a near-complete skeleton. The full-mount *Stegosaurus* on exhibit is also from Garden Park in Fremont County. Both the 1992 find of a complete skeleton and the 1993 restoration of the Museum's 1937 mounted skeleton have led to new conclusions about the animal's use of its plates and spikes. *Stegosaurus* was originally discovered in Morrison, Colorado.

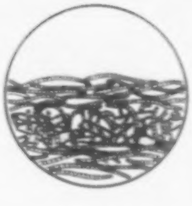


Stenomylus

Stenomylus—sten-o-MILE-us
A small, gazelle-like camel that lived during the Miocene Epoch. Camels later migrated to South America, evolving into llamas, alpacas, vicunas, and guanacos, and to Asia, evolving into bactrian and dromedary camels.

192

stratigraphy
The study of the relationships of rock layers over geologic time and geographic space.



stromatolite

stromatolite—strow-MAT-o-lite
A layered sedimentary rock formed by microorganisms (like blue-green algae/cyanobacteria) that trap and bind sediment to form a living platform. Stromatolites are the Earth's oldest fossils (3.5 billion years old).

Stygimoloch—STIG-ee-MOLE-ock
Stygimoloch was a dinosaur that had sharp head spikes and a thick skull. It lived during the Late Cretaceous Period. It was a type of pachycephalosaur, or bony-headed dinosaur. It was an herbivore.

T

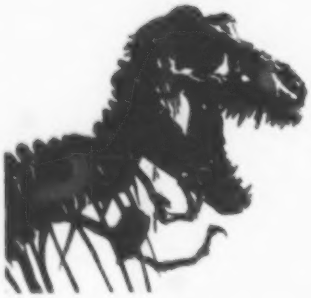
taphonomy
The study of all processes occurring between the death of an organism and the excavation of its fossil (the study of burial).

thecodont
A group of reptiles that included the ancestors of dinosaurs and some other Mesozoic reptiles. All were extinct by the end of the Triassic.

titanothere—tie-TAN-o-theers
Animals with horse-like bodies and rhino-like heads that ate leaves and twigs and were once one of the largest and most common North American mammals. They lived during the Eocene Epoch, 48 million years ago.

Triceratops—try-SAIR-uh-tops
An herbivorous, three-horned dinosaur that lived during the Late Cretaceous Period. Originally found in Denver, Colorado.

Trigonias—try-GO-knee-us
An early rhinoceros that living during the Miocene Epoch and had no horn on the snout and more teeth in the jaw than modern rhinos.



Tyrannosaurus rex

trilobites—TRY-low-bites
An early kind of arthropod, they were the first animals to develop eyes, legs, segmented protective shells, antennae, gills, and mouths. These creatures fed on organic debris along the sea floor and are now extinct.

Tyrannosaurus rex—tie-ran-o-SORE-us wrecks
The largest of all carnivorous dinosaurs. They walked on their hind legs, were approximately 35 feet long, and weighed 6 tons. Its fore limbs are small but may have been used to hold its prey. It had a massive head and 6-inch-long teeth and was probably a fast runner.

U

uintathere—you-In-ta-theer
The biggest, strangest mammal of the Eocene Epoch lived 47 million years ago. They were plant-eaters with sabertoothed canines and knobs on their heads and died out about 45 million years ago, leaving no modern relatives.

V

vertebrate
An animal with a backbone. Living vertebrates include jawless fishes (lampreys), sharks, bony fishes, amphibians, reptiles, birds, and mammals. Vertebrates originated approximately 500 million years ago.

W

warm-blooded (endotherm)
Active animals that produce their own heat and maintain a constant temperature.

PREHISTORIC JOURNEY℠

Denver Museum of Natural History
2001 Colorado Boulevard • Denver, Colorado 80205 • 322-7009

PREHISTORIC JOURNEY POINTERS

PLANNING YOUR VISIT

How to Make the Most of Your Visit to *Prehistoric Journey*

LOGISTICS

1.
Have reservation number and blank check ready.

2.
Decide on lunch times and organization.

3.
If it's a large group and there is a time crunch, have one adult handle all the "entrance to the Museum" details.

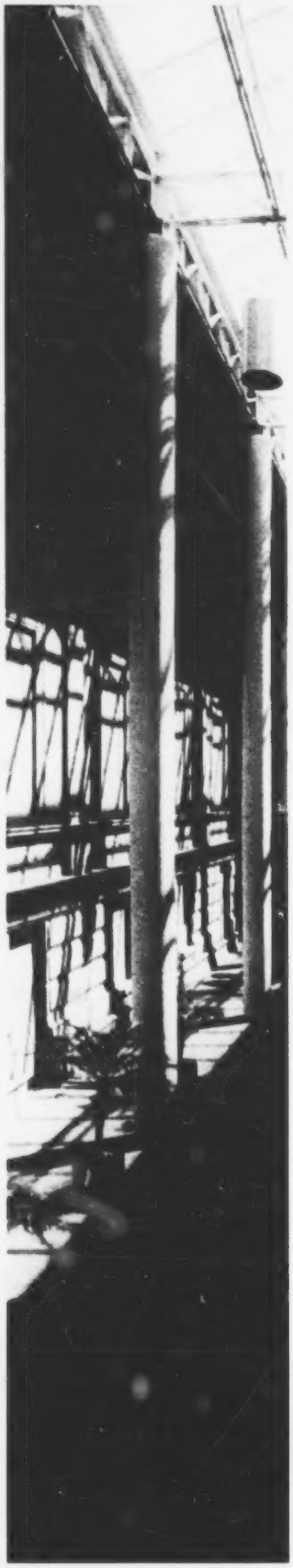
4.
Make sure adult group leaders have a pre-trip orientation to academic and behavior expectations.

5.
Prepare students with all the logistic information so they know where they will be going and when.

TEACHER TIP

- *Decide on the main purpose for your visit. Your students may be conducting research on certain topics, you may be involved in a special project or enrichment, for part of a curriculum unit, or this may just be a special treat for your students.*
- *Visit the Museum yourself before your field trip date to get ideas for pre-, during-, and post-visit assignments and Museum logistics.*
- *Prepare students with good pre-lessons like the ones in this Sourcebook—Investigation Units so they have "intellectual hooks" on which to hang the* Prehistoric Journey *experience.*
- *Provide students with "assignments" during their visit—some strategies include structured study guides, verbal "think about" questions, journal entries, and during-visit activities from this Sourcebook.*
- *No matter what the purpose for the* Prehistoric Journey *trip, good post-visit lessons and activities make it important and of lasting value to students. Students need to know what they learned from their "field experience."*
- *Develop a Museum experience "itinerary" to share with students and adult group leaders.*

Gail Schatz
Learning Coordinator,
North Middle School



Due to the Museum's desire to provide a focused, quality learning environment within the exhibit, **a limited number of school groups** will be able to visit the exhibit from October 1995 through May 1996.

The following information will be valid until May 1996. Please check the next Museum school brochure for updated information in the second and subsequent years of *Prehistoric Journey* school visits.

HOURS

School group start times are Monday through Friday at 9:00 A.M. and 11:40 A.M. The cost will be $1 per student. Students will enter the exhibit every eight minutes, in groups no larger than 18. This will necessitate dividing your students into groups of not more than 18, with two school-provided chaperones per group. Exhibit access is on a timed entry basis only. 9:00–11:40 A.M., Monday–Friday.
Nonguided entry times are 9:00–9:16 A.M.; 9:56–10:42 A.M.; and 11:32–11:40 A.M. (entering every eight minutes).
Guided tours are every eight minutes 9:24–9:48 A.M. and 11:00–11:24 A.M., Monday–Thursday.

PRICING

Teachers will be admitted free to the Museum. Chaperones will be charged the student rate of $1.

SCHEDULING YOUR VISIT

- Call 322-7009, seven days a week, 9:00 A.M.–5:00 P.M. Reservations must be made at least three weeks in advance.
- Have alternative dates and times in mind before calling for reservations.
- A confirmation packet will be sent to you approximately two weeks prior to your visit.
- Check the confirmation for accuracy. Call 322-7009 immediately with any questions or corrections.

WHEN YOU ARRIVE

- You must arrive 20 minutes before your scheduled time slot to visit the exhibit.
- Bring your confirmation letter and group information with you.
- Use the School Entrance at the south side of the building. Greeters will direct your groups. You will be given instructions about where to put coats, backpacks, and lunches, and where you can eat lunch.
- Have group and program information and payment ready at this time. You will pay at the ticket counter inside the school entrance.
- Checks should be made payable to the Denver Museum of Natural History (one check, please). Cash payments should be in large bills to speed your admission process. Purchase orders are not accepted.

LATE ARRIVALS, RESCHEDULING, CANCELLATIONS

- If you will be arriving later than expected, please notify us at 322-7009.
- Due to the timed entry process, we may not be able to accommodate late arrivals without previous notification.
- To reschedule, call 322-7009. Please be aware that we may not be able to reschedule you because of the heavy demand to view this exhibit.
- When cancellations are necessary, please call 322-7009 at least three business days in advance. Cancellations made less than three business days in advance are subject to a $25 fee, to cover the time and expense involved in planning your program.

RELATED PROGRAM OFFERINGS

To round out your visit to *Prehistoric Journey*, consider scheduling related program offerings. In addition to tours of the exhibit, we offer Classroom Adventures and Planetarium Programs that directly relate to the exhibit. Many of our other exhibit tours and classes can enhance the educational goals for your visit as well. If you are looking for a resource to come to your classroom, schedule one of the Worlds of Wonder outreach programs that relate to *Prehistoric Journey*.

TEACHER WORKSHOPS

We strongly encourage each teacher planning to visit *Prehistoric Journey* to attend a teacher workshop to help create the best possible experience for students.

At *Prehistoric Journey* Teacher Workshops, you will

- Meet the Museum's paleontologists, whose scientific research provides the basis for the information and environmental reconstructions presented in the exhibit.
- Gain a better understanding of the history of life on Earth.
- Take a behind-the-scenes tour of the exhibit.
- Learn how to get the most out of your visit with your students.
- Explore different options for touring the exhibit.
- Receive information on meeting state standards for science teaching through your visit.
- Participate in hands-on activities that tie into exhibit concepts and utilize fossils in the Museum's education collections.
- Receive a copy of the *Prehistoric Journey* Educators' Sourcebook.
- Learn about other Museum programs that expand on concepts presented in *Prehistoric Journey*.

A one-day workshop will be offered January 20, 1996, and others are planned for the future. For more information about current teacher workshops, call 322-7009.

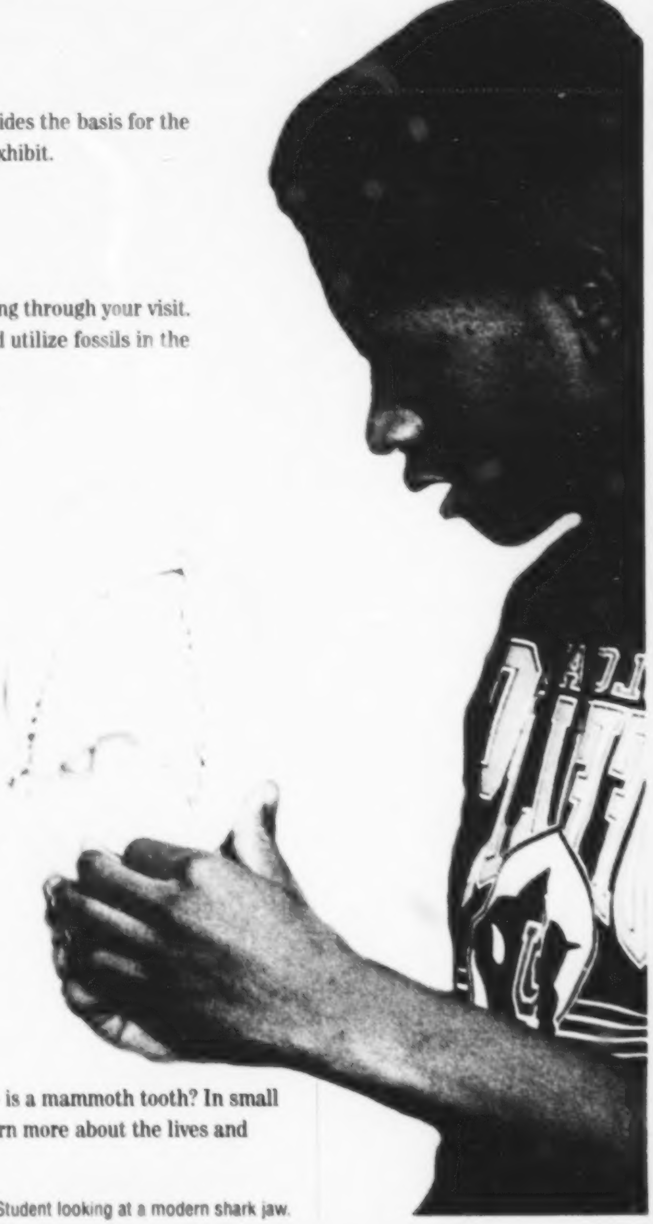
CLASSROOM ADVENTURES

For more in-depth coverage of prehistoric topics, register for Classroom Adventure hands-on art classes and learning labs by calling 322-7009. Our 1995–1996 offerings include the following:

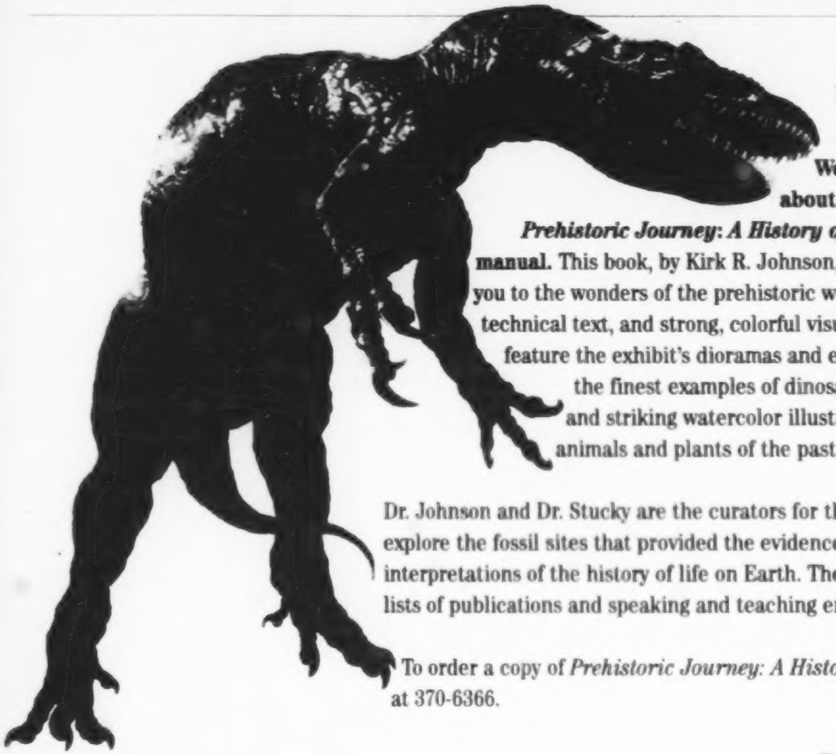
- **Colorado Fossils Through Time (Grades 3–9)**
  Review geologic time, discover methods of fossilization, and learn about Colorado's landscape and inhabitants through time. Visit hands-on stations with fossil specimens and activities.

- **Dinosaur Mask-Making (Grades K–5)**
  Touch real fossil specimens and create your own dinosaur mask.

- **Trilobites to Tyrannosaurs (Grades 1–4)**
  How do we know that dinosaurs once roamed Colorado? How large is a mammoth tooth? In small groups, students examine footprints, bones, and other fossils to learn more about the lives and habitats of prehistoric plants and animals.



Student looking at a modern shark jaw.



PREHISTORIC JOURNEY: A HISTORY OF LIFE ON EARTH—EXHIBIT BOOK

We suggest that all teachers wishing to learn more about the science behind *Prehistoric Journey* purchase *Prehistoric Journey: A History of Life on Earth* as a companion volume to this manual. This book, by Kirk R. Johnson, Ph.D. and Richard K. Stucky, Ph.D., will introduce you to the wonders of the prehistoric world through world-class fossils, an accessible, non-technical text, and strong, colorful visuals. Dramatic color illustrations and photographs feature the exhibit's dioramas and enviroramas; spectacular fossils, including many of the finest examples of dinosaurs, large mammals, early primates, and giant fish; and striking watercolor illustrations that accurately render the evolution of the animals and plants of the past.

Dr. Johnson and Dr. Stucky are the curators for the *Prehistoric Journey* exhibit. In the text, they explore the fossil sites that provided the evidence for the exhibit's dioramas, enviroramas, and other interpretations of the history of life on Earth. They are noted experts in their fields with extensive lists of publications and speaking and teaching engagements.

To order a copy of *Prehistoric Journey: A History of Life on Earth*, call the Museum Shop at 370-6366.

TOURS

Three guided tours will be offered in *Prehistoric Journey* during the 1995–1996 school years. These tours were developed with input from area K–12 teachers. On page 102 of this Sourcebook, we discuss these tours, as well as provide suggested pathways for two self-guided tours and suggested pre- and post-visit activities. All *Prehistoric Journey* tours are correlated with the Colorado Model Content Standards for science teaching. To register for a guided tour, call 322-7009.

PRE-VISIT VIDEO FOR TEACHERS

The *Prehistoric Journey* pre-visit teacher video will introduce teachers and students to the exhibit. It will have a brief, introductory section designed to excite students about their upcoming field trip to the exhibit. This portion will be translated into Spanish for Spanish-speaking students. Following that, an extended portion will acquaint teachers with *Prehistoric Journey* and the rich educational resources it offers to area teachers. SCFD area schools will receive a copy of this video. To order a copy of this video, call 370-6314. A copying and shipping fee may be required.

Prehistoric
Universe

PLANETARIUM SHOW: PREHISTORIC UNIVERSE

What existed before life originated on Earth? Gain an even fuller understanding of our planet and its place in the universe with a new show in the Gates Planetarium. This presentation, created specifically to tie into the *Prehistoric Journey* exhibit, will trace the history of the universe from its formation, billions of years ago, to the formation of the Earth. This show will teach students how the solar system and the Earth formed, discuss the life cycles of stars, and explain how the heavy elements in the universe were formed. An interactive segment will discuss the methods astronomers have used to find out about places they can never visit using chemical "fingerprints" and explain how they have attempted to measure the size and age of the universe itself. Please plan to join us in the Gates Planetarium as part of your visit to the *Prehistoric Journey* exhibit. Recommended for grades 5 and up.

Denver M
tory

WOW PROGRAMS

Enjoy creative science lessons with options to fit almost any need or budget. Choose an Assembly or the WOW Van for an all-school special event. *Prehistoric Journey*–related programs include the Discovery Lesson *Can You Dig It?* and a *Prehistoric Journey* assembly program. For reservations, call 370-6371.

GALLERY PRESENTATIONS

Gallery presentations on *Prehistoric Journey*–related subjects will be presented in the exhibit during non-school hours (after noon).

ADULT PROGRAMS

Adult Programs offered by the Museum will add to your knowledge of the history of life on Earth. Lectures by noted scientists, symposia, and special tours through the exhibit led by Museum staff are available. For more information on Adult Programs call 370-6303.

The Museum's Paleontology Certification Program is a model program allowing amateurs to obtain certification in paleontological methods and techniques. For more information on this program, call 370-8287.

MUSEUM SHOP

The Museum Shop carries books, posters, toys, and other teacher resources related to *Prehistoric Journey*. Call 370-6366 to find out what's available.

APPENDIX

Adopted Colorado State Standards related to *Prehistoric Journey* themes

Based on the *Colorado Model Content Standards for Science*
Adopted 5-10-95
Printed 6-2-95

Trilobite fossil

SCIENCE

Grades K–4, 5–8, and 9–12

Standard 1: Students understand the processes of scientific investigation and are able to design, conduct, communicate about, and evaluate such investigations.

In grades K–4, what students know and are able to do includes:

- asking questions and stating predictions that can be addressed through scientific investigation;
- selecting and using simple devices to gather data related to an investigation;
- using data based on observations to construct a reasonable explanation; and
- communicating about investigations and explanations.

As students in grades 5–8 extend their knowledge, what they know and are able to do includes:

- identifying and evaluating alternative explanations and procedures;
- using examples to demonstrate that a scientific theory is used to explain previous observations and to predict future events;
- using appropriate tools, technologies, and measurement units to gather and organize data;
- interpreting and evaluating data in order to formulate conclusions;
- communicating results of their investigations in appropriate ways; and
- explaining that new scientific ideas sometimes result in unexpected findings that lead to new questions and more investigations.

As students in grades 9–12 extend their knowledge, what they know and are able to do includes:

- asking questions and stating hypotheses, using prior scientific knowledge to help guide their development.
- creating and defending a written plan of action for a scientific investigation;
- selecting and using appropriate technologies to gather, process, and analyze data and to report information related to an investigation;
- communicating and evaluating scientific thinking that leads to particular conclusions; and
- recognizing and analyzing alternative explanations and models.

Standard 3: Students know and understand the characteristics and structure of living things, the processes of life, and how living things interact with each other and their environment.

3.1 Students know and understand the characteristics of living things, the diversity of life, and how living things interact with each other and with their environment.

In grades K–4, what students know and are able to do includes:

- distinguishing living from nonliving things;
- classifying a variety of organisms according to selected characteristics; and
- giving examples of how organisms interact with each other and with nonliving parts of their habitat.

PREHISTORIC JOURNEY
TEACHER SOURCEBOOK EVALUATION FORM

Denver Museum of Natural History

Please complete the following questionnaire and mail it back to us. Your comments and opinions are very important to us.

What grade do you teach: K 1 2 3 4 5 6 7 8 9 10 11 12

How many years have you been teaching?________

Do you teach in a: ☐ Public School ☐ Private School ☐ Home School

What district do you teach in?________________________________

1. Have you taken your class to visit *Prehistoric Journey*?

____

2. How was this Sourcebook useful in planning your visit to *Prehistoric Journey*?

____

____

Was the format user-friendly? ______________________________

How could it be improved? ______________________________

3. Was the content written and organized in an understandable manner?

☐ Yes ☐ No ☐ Undecided ☐ Didn't use

Comments: ______________________________________

4. Were the maps of the Evidence Areas useful?

☐ Yes ☐ No ☐ Undecided ☐ Didn't use

How were they useful:

prior to your visit? ______________________________

during your visit? ______________________________

5. Were the Background Information sections useful?

☐ Yes ☐ No ☐ Undecided ☐ Didn't use

How could these sections be improved?

____

(continued on the back)

200

6. Which of the activities from the Investigation Units have you conducted? ____________________

How did they work? ____________________

Were they age-appropriate? ____________________

How could we improve them? ____________________

____

7. Were the guided tour descriptions adequate? ____________

8. Have you conducted any of the self-guided tours in the Sourcebook? ____________

How did they work? ____________________

____

____

How can we improve the self-guided tours to make them more useful?

____

____

9. Did you find the Glossary helpful?

____

10. Have you taken your classroom on one of the field trips in the Colorado Connections section?

____

11. What information did you need that you could not find in this Sourcebook?

____

____

____

12. I would recommend this Sourcebook to others. ☐ Yes ☐ No

Thank you for taking the time to complete this evaluation form.
Please mail to:
Denver Museum of Natural History
Youth Programs Department–Sourcebook Survey
2001 Colorado Boulevard
Denver, CO 80205

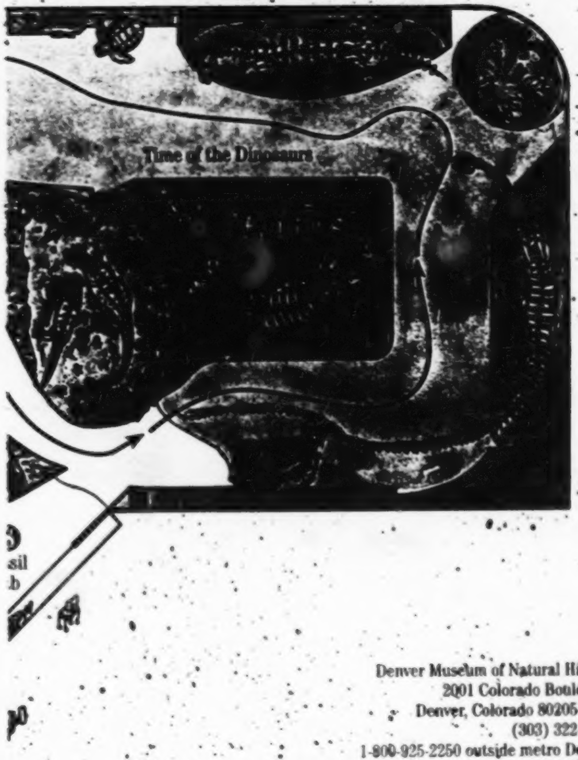
Diorama Scenes

1. Ancient Sea Floor
2. Sea Lily Reef
3. Between Two Worlds
4. Kansas Coastline
5. Cretaceous Creekbed
6. Rainforest Treetop
7. Nebraska Woodland
8. Earth Sciences Lab

There are lots of fossils you're allowed to touch in Prehistoric Journey.

But please leave the others alone, even if you can reach them.

Fossils are fragile and irreplaceable.



Denver Museum of Natural History
2001 Colorado Boulevard
Denver, Colorado 80205-5798
(303) 322-7009
1-800-925-2250 outside metro Denver
TDD 370-8257

Open seven days a week except Christmas Day.

The Denver Museum of Natural History gratefully acknowledges the support of the voters of the Scientific and Cultural Facilities District. Major funding for this trail guide and the Prehistoric Journey exhibition was also provided by the National Science Foundation.

SCFD
Scientific & Cultural Facilities District

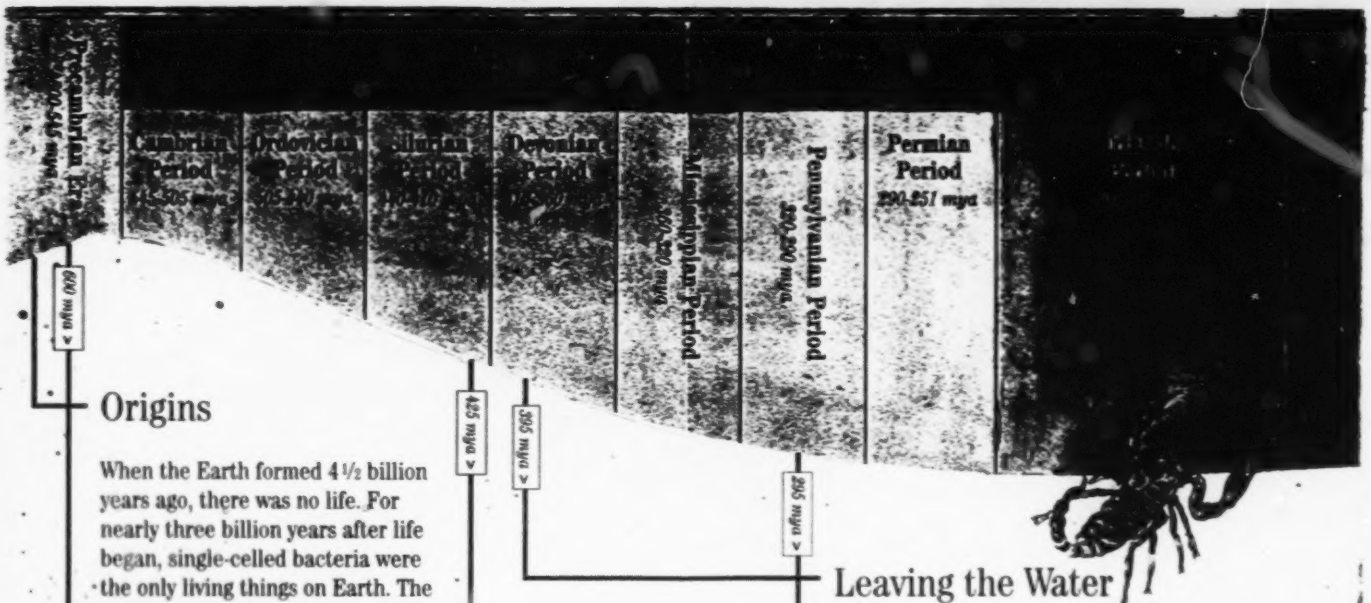
© 1996 DMNH

Printed on recycled paper

ISTORIC
JOURNEY

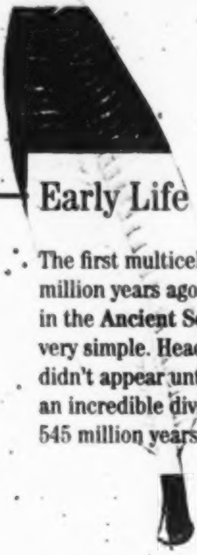
The Denver Museum of Natural History

BEST COPY AVAILABLE


Precambrian Era
600-545 mya
Cambrian Period
545-505 mya
Ordovician Period
505-440 mya
Silurian Period
Devonian Period
Mississippian Period
360-320 mya
Pennsylvanian Period
320-290 mya
Permian Period
290-251 mya
600 mya
425 mya
395 mya
295 mya

Origins

When the Earth formed 4 ½ billion years ago, there was no life. For nearly three billion years after life began, single-celled bacteria were the only living things on Earth. The bacteria sometimes formed colonies in shallow water along the shore.



Early Life

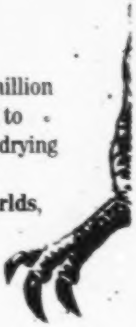
The first multicellular life evolved about 600 million years ago. These life forms, like the ones in the **Ancient Sea Floor**, were bigger but still very simple. Heads, legs, tails, and hard parts didn't appear until the Cambrian Explosion–an incredible diversification of underwater life 545 million years ago.

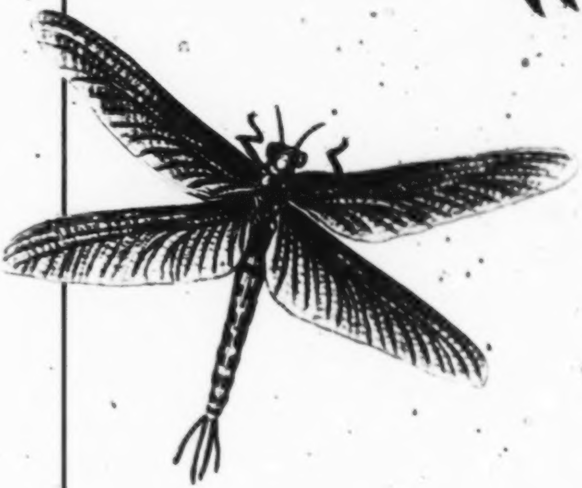
Diversity in the Sea

Over time, life in the sea became more varied and complex. By 425 million years ago, there were vibrant reef systems like the one in the **Sea Lily Reef**. Shelled animals such as trilobites, brachiopods, and cephalopods were everywhere, and the first fish evolved.

Leaving the Water

Life had begun to venture onto land 395 million years ago. Moving onto land meant having to breathe air, stand upright, and keep from drying out. Plants were followed by scorpionlike arthropods, as shown in **Between Two Worlds**, and later by amphibians.

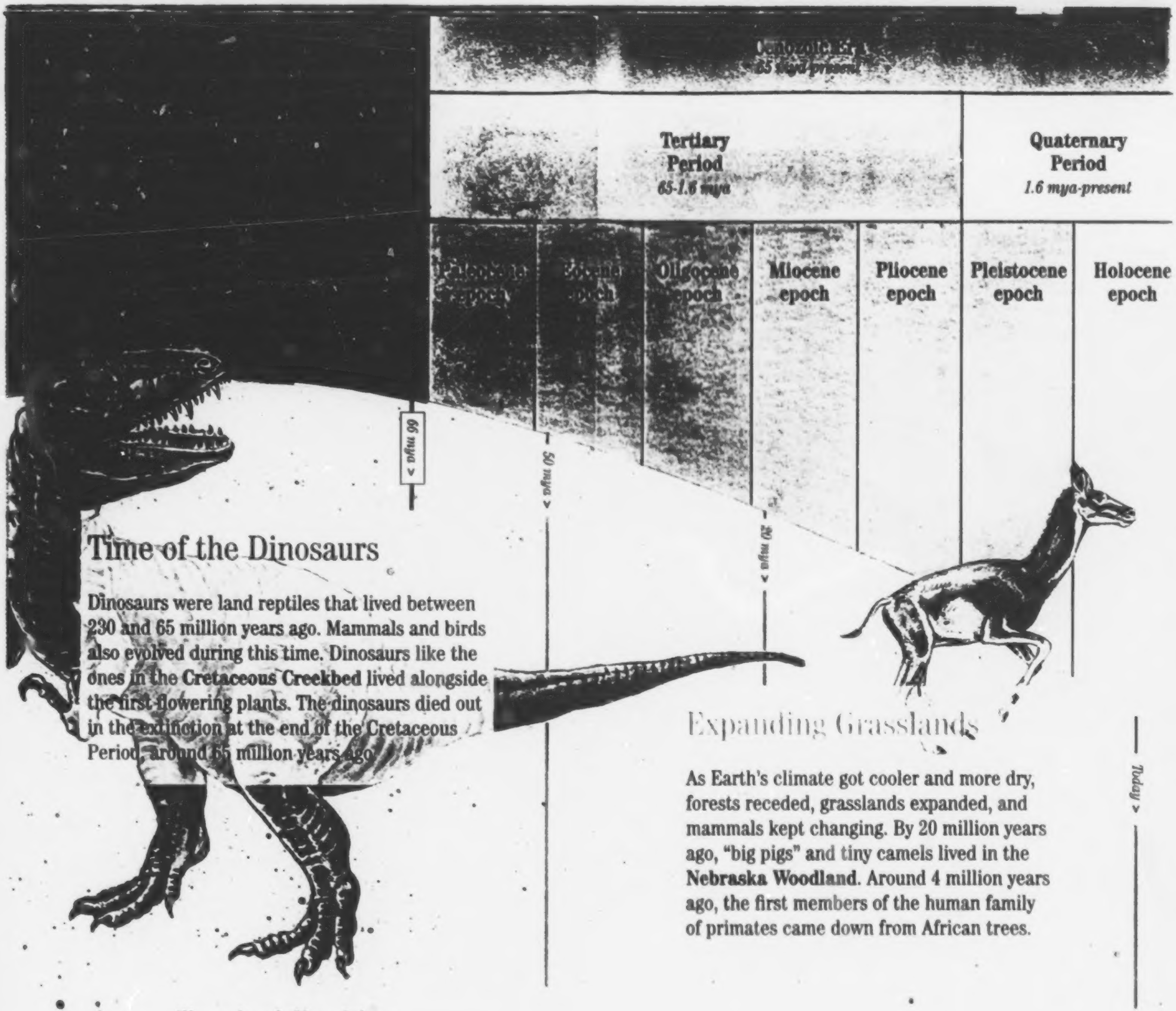




Forests and Flight

By the time of the 295-million-year-old **Kansas Coastline,** reptiles, big amphibians, and huge flying insects lived among forests of primitive trees. Then, around 250 million years ago, the biggest extinction of all time wiped out many life forms on land and sea.

BEST COPY AVAILABLE


Cenozoic Era
65 mya-present
Tertiary Period
65-1.6 mya
Quaternary Period
1.6 mya-present
Paleocene epoch
Eocene epoch
Oligocene epoch
Miocene epoch
Pliocene epoch
Pleistocene epoch
Holocene epoch
66 mya >
50 mya >
20 mya >
Today >

Time of the Dinosaurs

Dinosaurs were land reptiles that lived between 230 and 65 million years ago. Mammals and birds also evolved during this time. Dinosaurs like the ones in the **Cretaceous Creekbed** lived alongside the first flowering plants. The dinosaurs died out in the extinction at the end of the Cretaceous Period, around 65 million years ago.

Expanding Grasslands

As Earth's climate got cooler and more dry, forests receded, grasslands expanded, and mammals kept changing. By 20 million years ago, "big pigs" and tiny camels lived in the **Nebraska Woodland**. Around 4 million years ago, the first members of the human family of primates came down from African trees.

Tropical Rockies

50 million years ago, Earth's climate was very warm. Colorado and Wyoming were covered with vast rainforests. With the dinosaurs gone, mammals diversified into many different kinds, including primates like the ones in the **Rainforest Treetop**.

Fossil Lab

Through the window of the **earth sciences laboratory**, you can watch scientists and technicians study and prepare fossils–using modern technology to unearth the mysteries of the Earth's past.

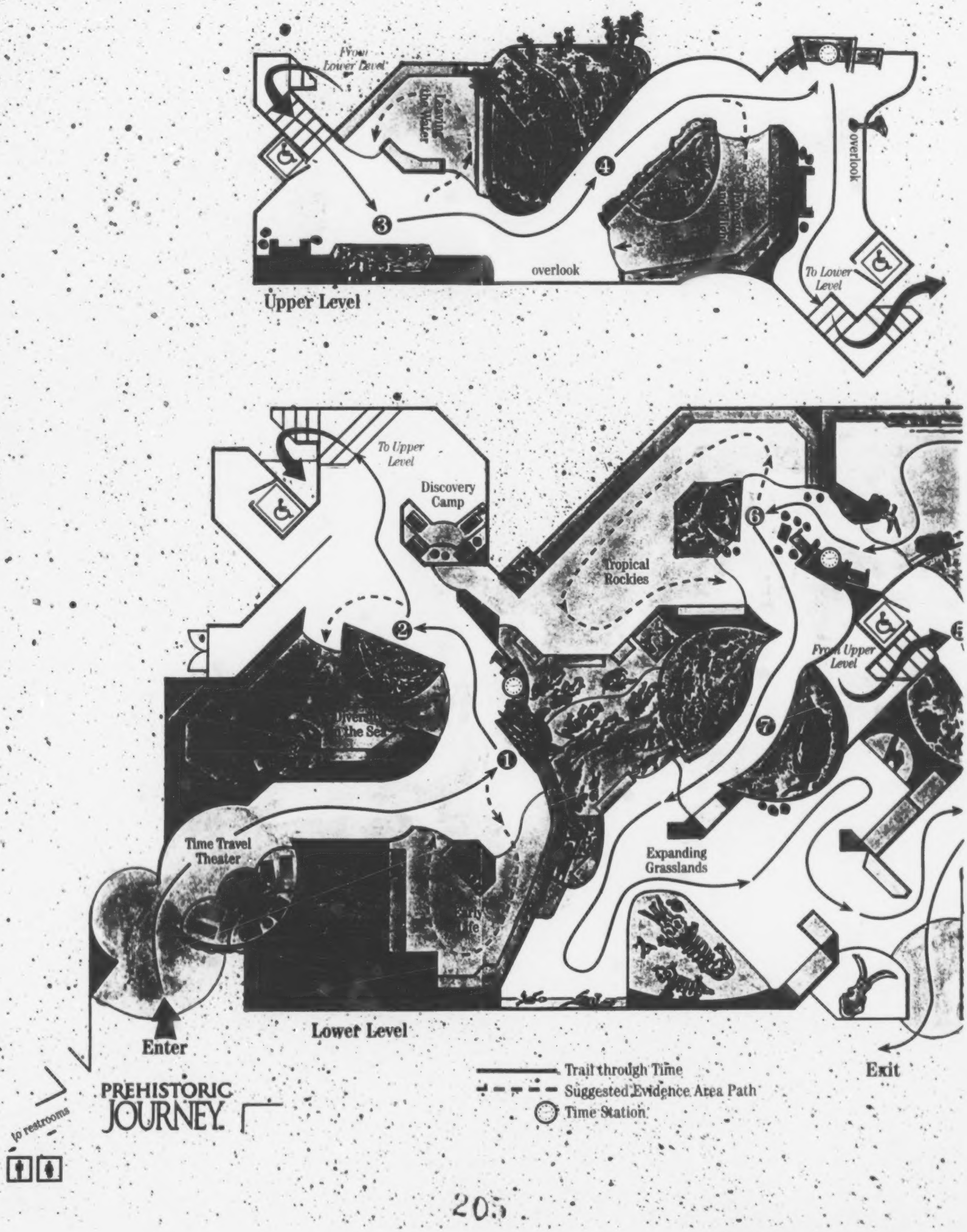
There is grandeur in this view of life. . .

from so simple a beginning

endless forms most beautiful and most wonderful

have been, and are being, evolved. Charles Darwin

BEST COPY AVAILABLE


From Lower Level
Leaving the Water
3
4
overlook
overlook
To Lower Level
Upper Level
To Upper Level
Discovery Camp
Tropical Rockies
6
2
Diversity in the Sea
1
7
From Upper Level
5
Time Travel Theater
Early Life
Expanding Grasslands
Enter
Lower Level
Exit
to restrooms
PREHISTORIC JOURNEY
Trail through Time
Suggested Evidence Area Path
Time Station

BEST COPY AVAILABLE